A Coordination Success for the Polar Science Communities

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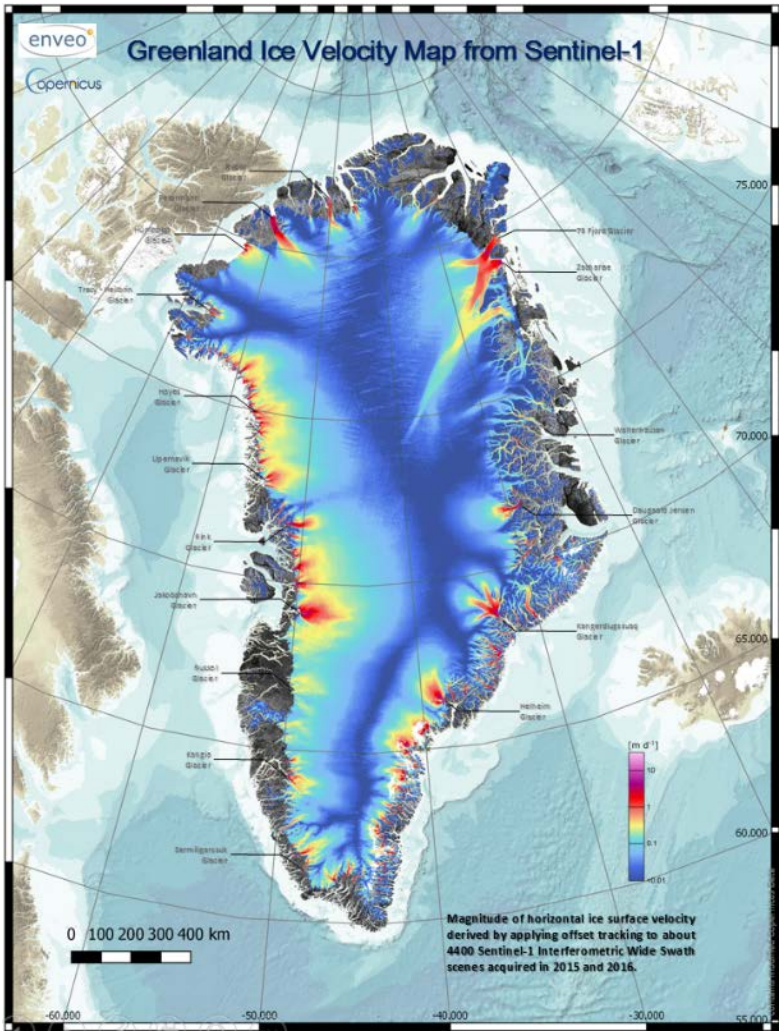
Presentation Outline

- Coordination
- Polar Space Task Group strategic themes
- Recent achievements only made possible through coordination
- Conclusion

SAR Coordination Working Group

- The SAR Coordination Working Group (SAR CWG) is a subsidiary group to Polar Space Task Group (PSTG)
- Provide tactical SAR response to PSTG strategic implementation plan
- Stimulate coordination
  - Among scientists for the development of requirements documents
  - Among space agencies to respond to the imaging requirements
  - Between the science community and space agencies for maintaining an open "dialogue" in order to put the "best minds" at work using the best technology assets possible



Credit: Nagler *et al.* 2015 *http://www.mdpi.com/2072-4292/7/7/9371*
Map contains modified Copernicus Sentinel data (2015) / ENVEO / ESA

Benefits of the Coordination

- Achievements only possible due to the inter-agency coordination on supporting the ambitious science questions with imaging activities.
- The coordination allows:
  - To distribute the imaging activities over multiple missions obtaining the same thematic results from different sensor increasing revisit, ensuring regional and continental coverage (sensor interoperability)
  - To complement data from various missions obtaining additional thematic information through the integration or synergistic use of two or more different sensors (sensor complementarity)
  - To support the acquisition of a unique dataset as an essential piece of information responding to a knowledge gap of the science question

Thematic Areas and Key Issues

POLAR SPACE TASK GROUP

HIGHLIGHT:

THEMATIC AREAS AND KEY ISSUES

Floating Ice

- Sea ice floe size, thickness and deformation
- Sea ice motion
- Sea ice melting characterization
- Iceberg dimensions and mass
- Iceberg calving rates
- Lake ice freeze up / breakup timing and characteristics
- Lake ice thickness, concentration and snow cover
- River ice freeze up and breakup timing and characteristics
- River ice thickness and snow cover

Permafrost

- Active layer monitoring
- Permafrost lake and thermokarst dynamics
- Map and monitor Arctic coastal permafrost zones

Snow

- Wide-area wet snow characterization, also in Alpine and forested situations
- Wet snow extent
- Seasonal snow melt period
- Snow melt extent and liquid water content

Ice Sheets (including glaciers)

- Ice sheet mass balance and modelling
- Ice sheet dynamics
- Ice sheet margins (grounding line and ice front)
- Ice sheet topography
- Changing morphology (crevices, shear margins)

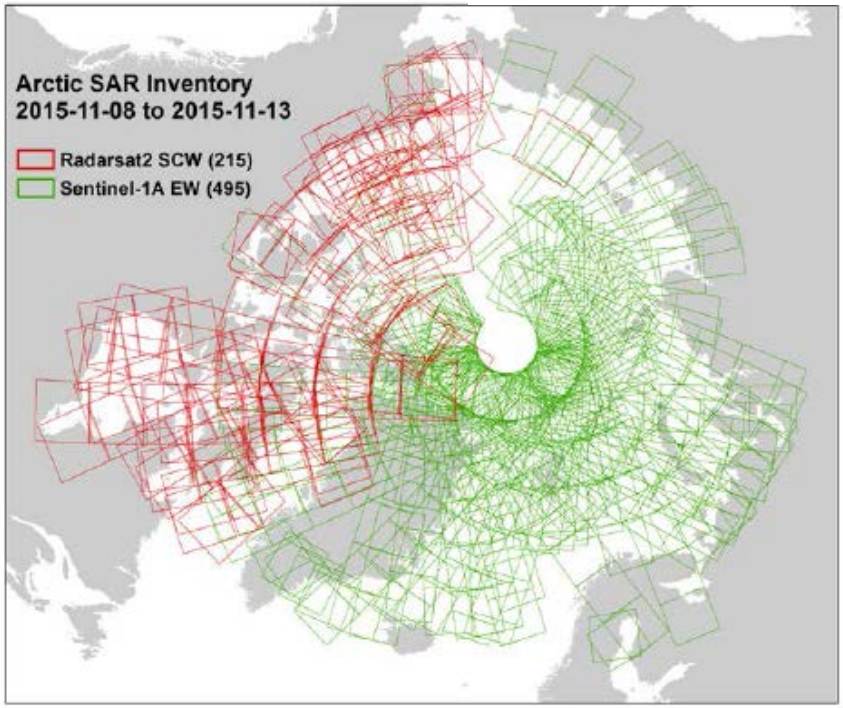
Science issues and data requirements have been documented and are available at *http://www.wmo.int/pages/prog/sat/pstg_en.php.*

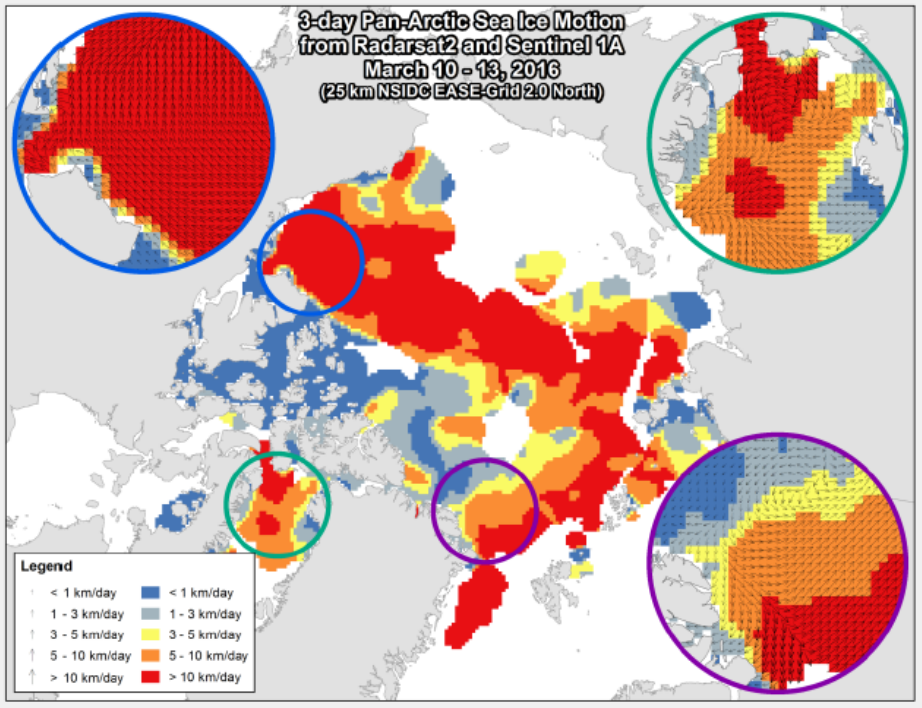
Sample of Science Requirements

- 1-3 day repeat pan-Arctic ocean SAR Imaging in support of sea ice motion;
- Yearly pan-Arctic basin imaging (early winter) @ coarse resolution for permafrost monitoring; and frequent imaging with multi-frequency high-res SAR over permafrost supersites;
- Daily observational requirements for satellite-based snow extent products for operational hydrology and climate research;
- Continent wide acquisition over ice sheets in InSAR configuration for velocity, grounding line and claving glaciers

Moving toward complete Arctic-wide coverage from SAR

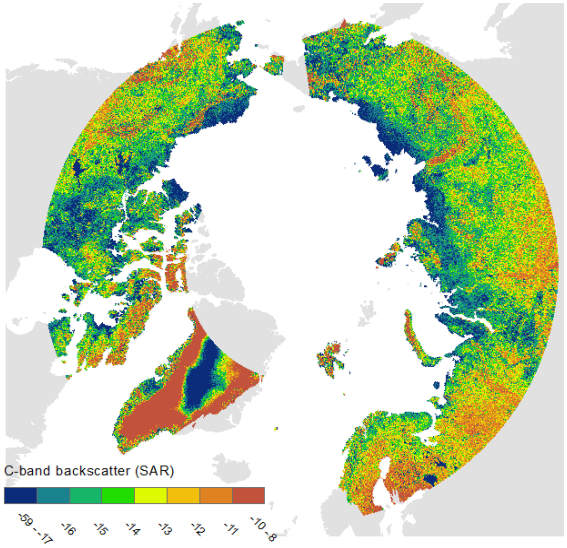
Environment and Climate Change Canada | Environnement et Changement climatique Canada





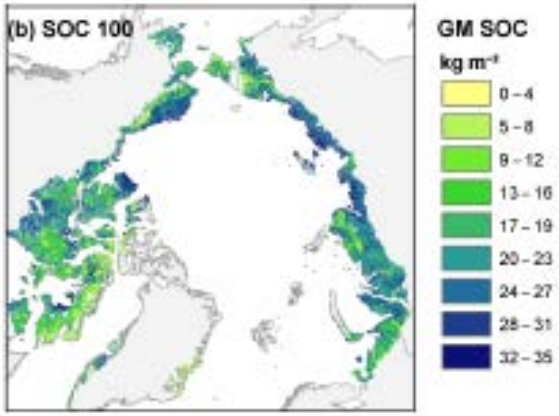
Establish a multi-agency plan for acquiring contiguous (seamless) six days repeat pan-Arctic SAR imaging at consistent polarization combination, with view to expanding to an intermediate goal of less than three days repeat in future with right-looking Sentinel-1 (S-1), RADARSAT Constellation Mission (RCM), etc.; and subsequently sub-daily data with C-, X-, S-, L-band SAR combined data sources

Permafrost Monitoring

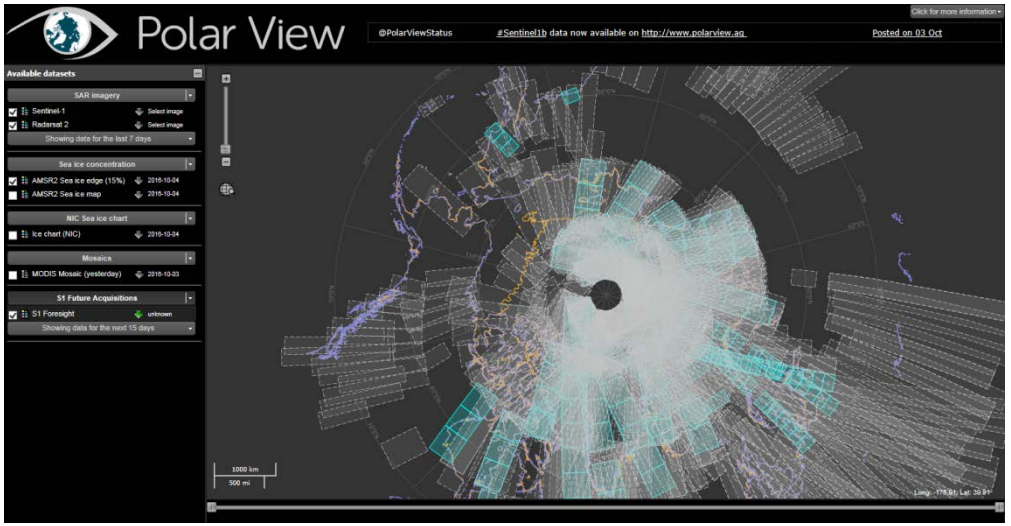


ASAR GM (C-Band winter Backscatter) TU Wien/FP7 project PAGE21 (Widhalm et al. 2015)

TerraSAR-X Cold Spot Permafrost Monitoring 1621 data takes in total Modes and polarizations: StripMap: HH, HH/VV, HH/HV, Spotlight: HH/VV



Soil Organic Carbone results from ENVISAT ASAR GM 0–100 cm - relates to soil properties important for heat conductivity. Bartsch, A. *et al* 2016

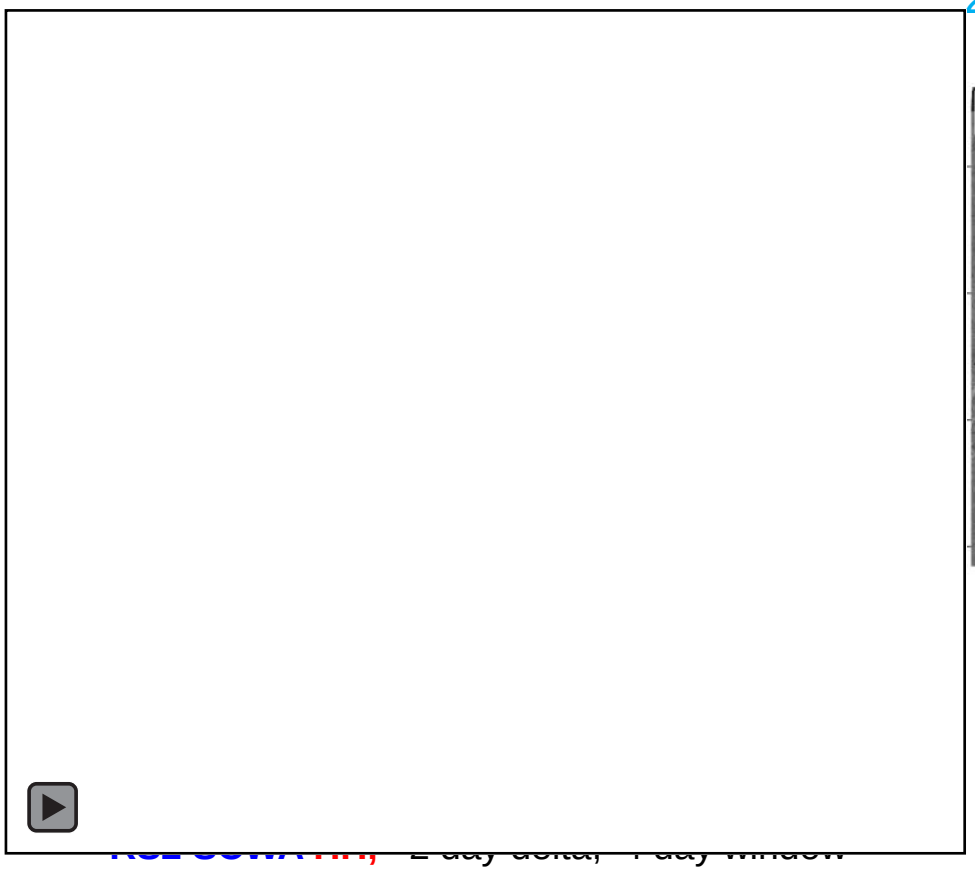


Monitoring melting snow using C-BAND SAR

Observational requirements for satellite-based **snow extent products** for operational hydrology and climate research (*IGOS Cryosphere Theme Report*):

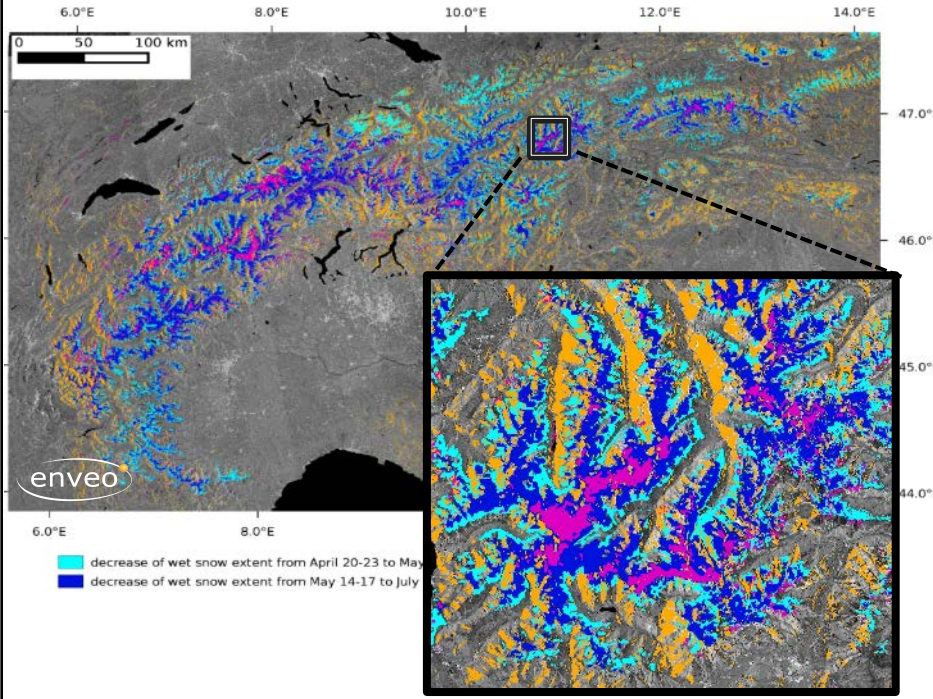
- Spatial resolution: 100 m
- Revisit time: 1 day

Time series of Backscatter – Ellesmere Is.



Retreat of snow extent from S1A- Alps

20-23 April 14-17 May 1-3 July 2015



Nagler et al., 2016

Wet snow observation with integrated Sentinel-1A and Radarsat-2

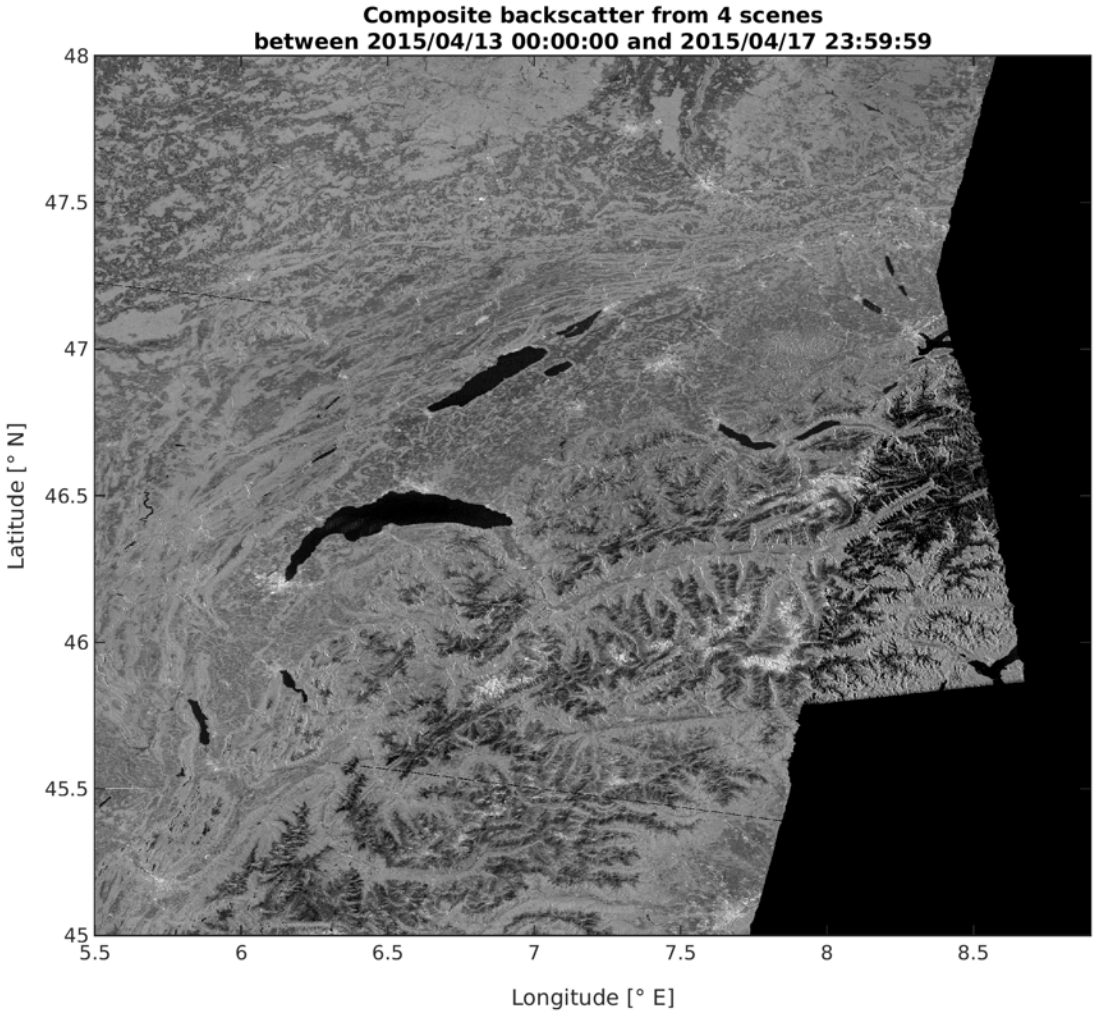
- Ascending/descending combination over western Switzerland

  Apr. 13-17, 2015

- Three desc. **S1A** IW products:
  Apr. 13, 2015
- One asc. **RS2** SCNB product:
  Apr. 17, 2015

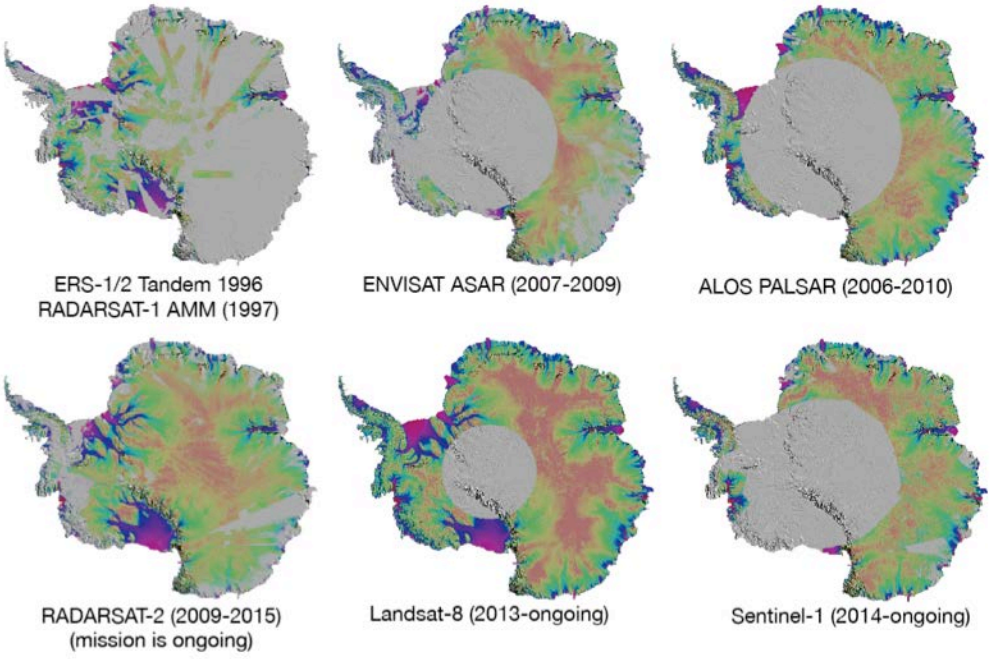
- *Hybrid* backscatter composite time series can be generated automatically from sets of available S1 and RS2 products

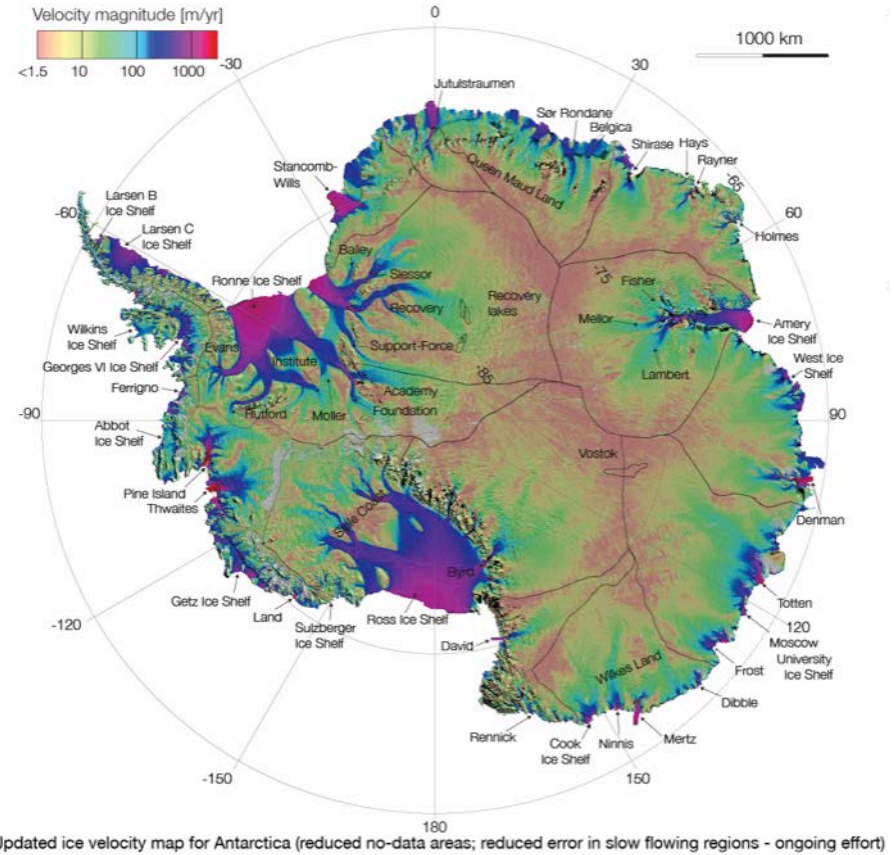
- Hybrid composites using multiple sensors provide *seamless ascending/descending coverage* with ***tighter time windows*** than when only 1 sensor can be used



Universität Zürich[UZH]

Continent-wide ice velocity information for Antarctica





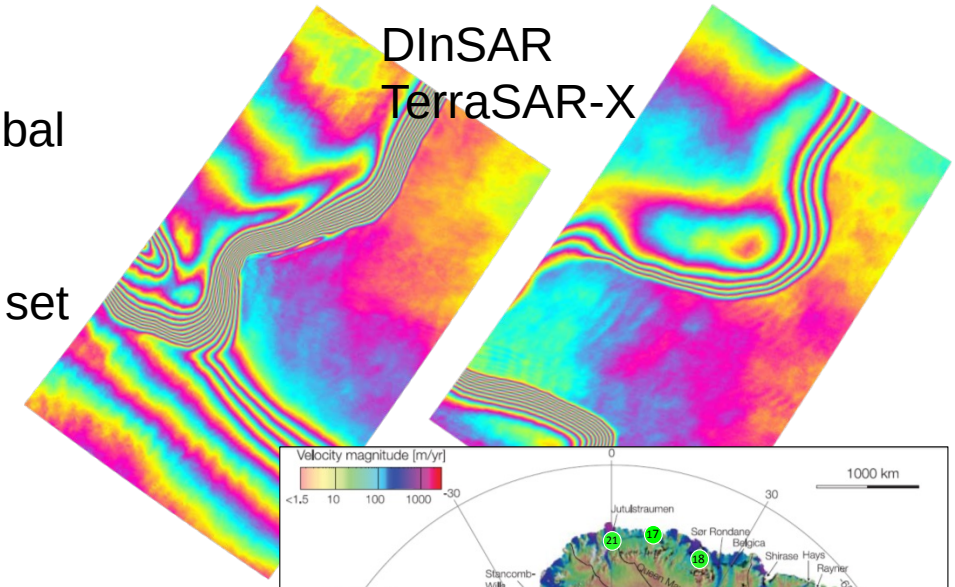
Updated ice velocity map for Antarctica (reduced no-data areas; reduced error in slow flowing regions - ongoing effort)

Courtesy of E. Rignot, J. Mouginot, and B. Scheuchl

Use of data from multiple SAR satellites and Landsat-8. High resolution X-band data is also integrated.

Earlier product version available at NSIDC: Rignot, et al. 2011a

TerraSAR-X & Antarctic Ice Sheet CCI

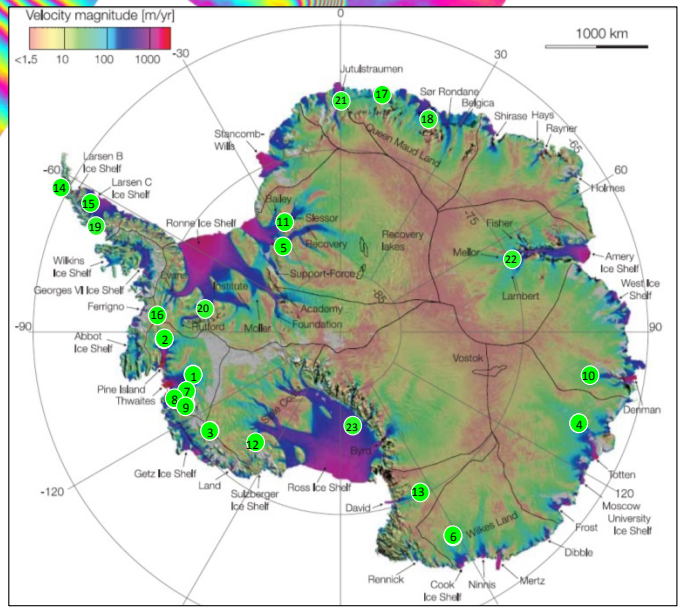


Ice sheets: belong to the 13 Environment Climate Variables (**ECV**s) identified by Global Climate Observation System (GCOS)

Aim: longterm and reliable production of a set of key parameters:

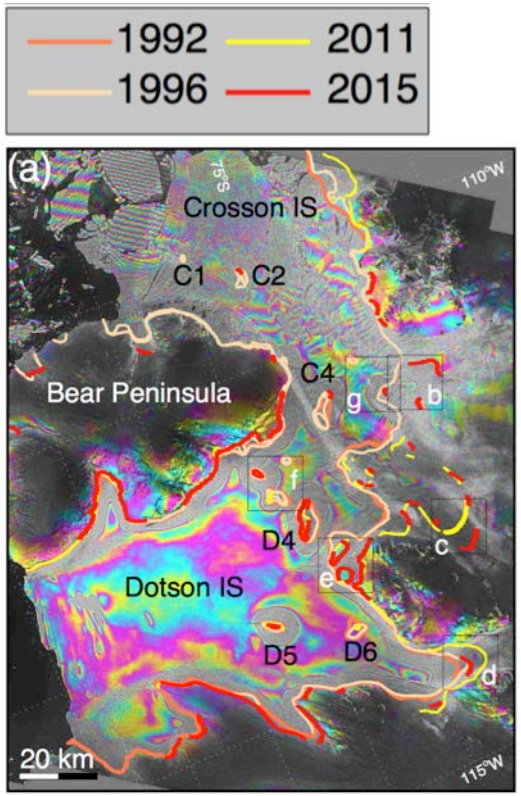
- Surface Elevation Change (SEC);
- **Ice Velocity (IV);**
- **Grounding Line Location (GLL);**
- Gravimetric Mass Balance (GMB)

http://www.esa-icesheets-antarctica-cci.org/



"SAR Science Requirements for Ice Sheets" (B. Scheuchl) recommendations → selection of **AIS_cci sites**

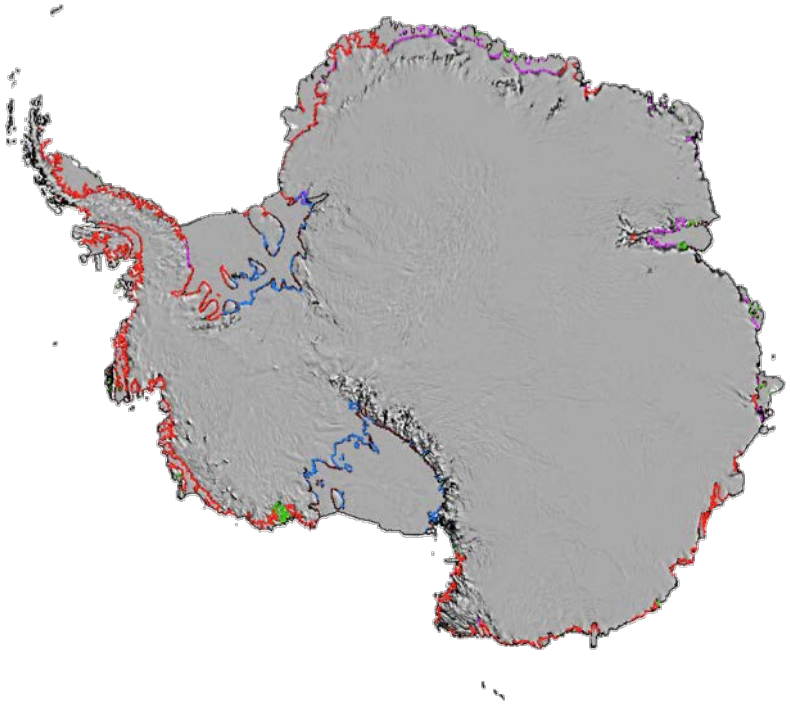
Continent-wide InSAR based grounding line product for Antarctica



Sentinel-1 based grounding line

Scheuchl, et al. 2016

Short revisit times and accurate DEM information are crucial for InSAR grounding line measurements.

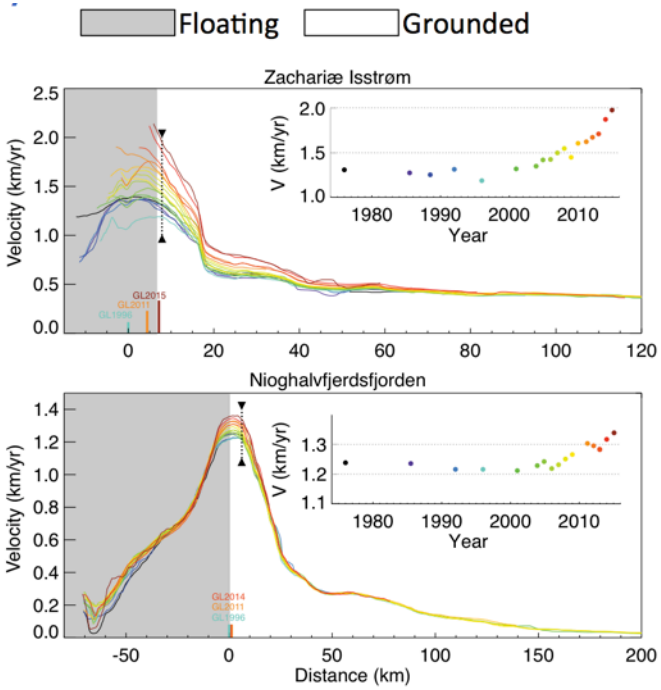


ERS1/2 (red) RADARSAT-1 (purple)
ALOS PALSAR (green) RADARSAT-2 (blue)

Product available at NSIDC: Rignot, et al. 2011b

40 Year Time Series Northeast Greenland

Spectacular changes of Zachariæ Isstrøm in recent years. Combining data from multiple sources allowed a 40 year record.

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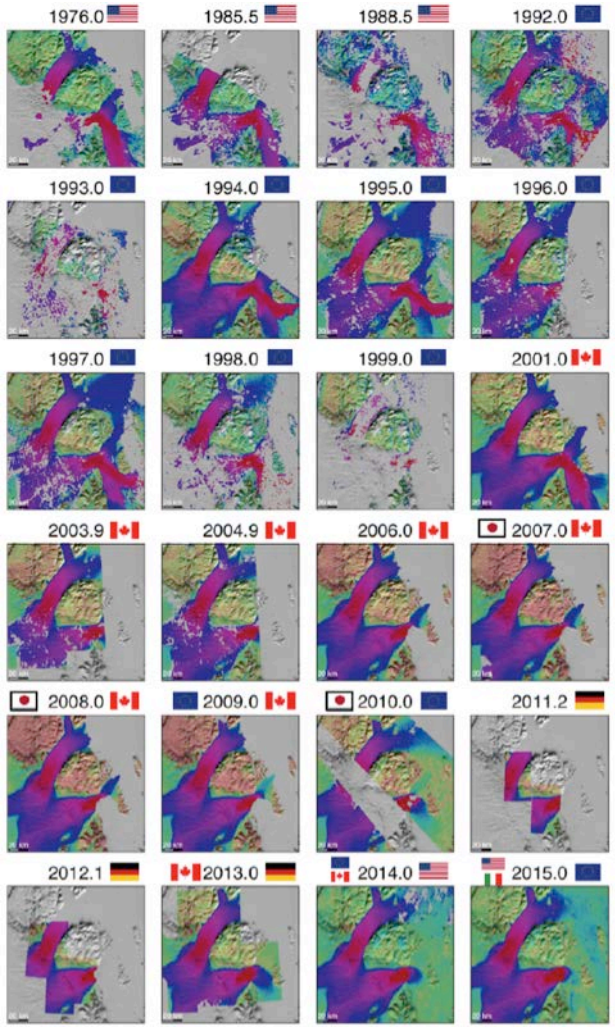
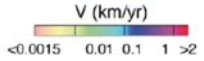
Fast retreat of Zachariæ Isstrøm, northeast Greenland
J. Mouginot, E. Rignot, B. Scheuchl, I. Fenty, A. Khazendar, M. Morlighem, A. Buzzi, J. Paden

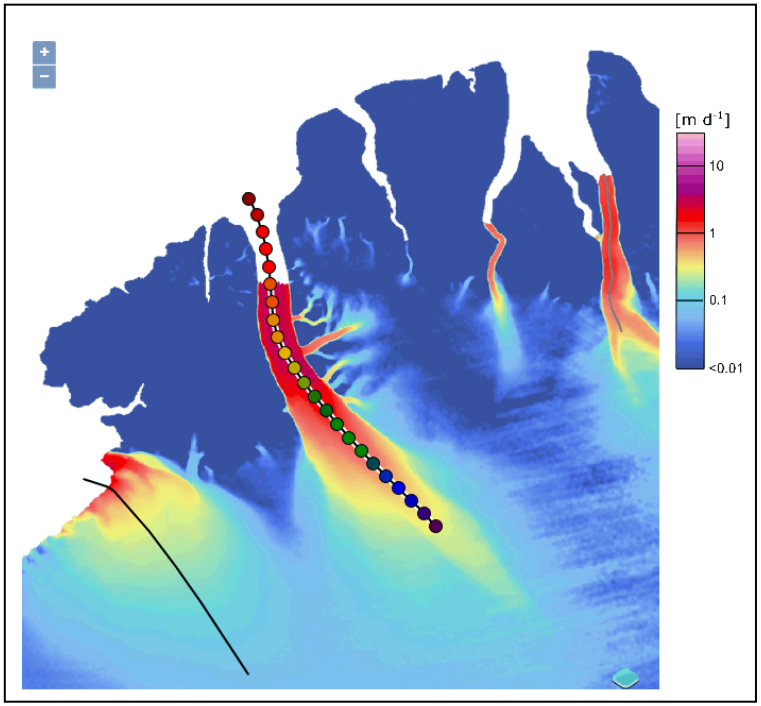


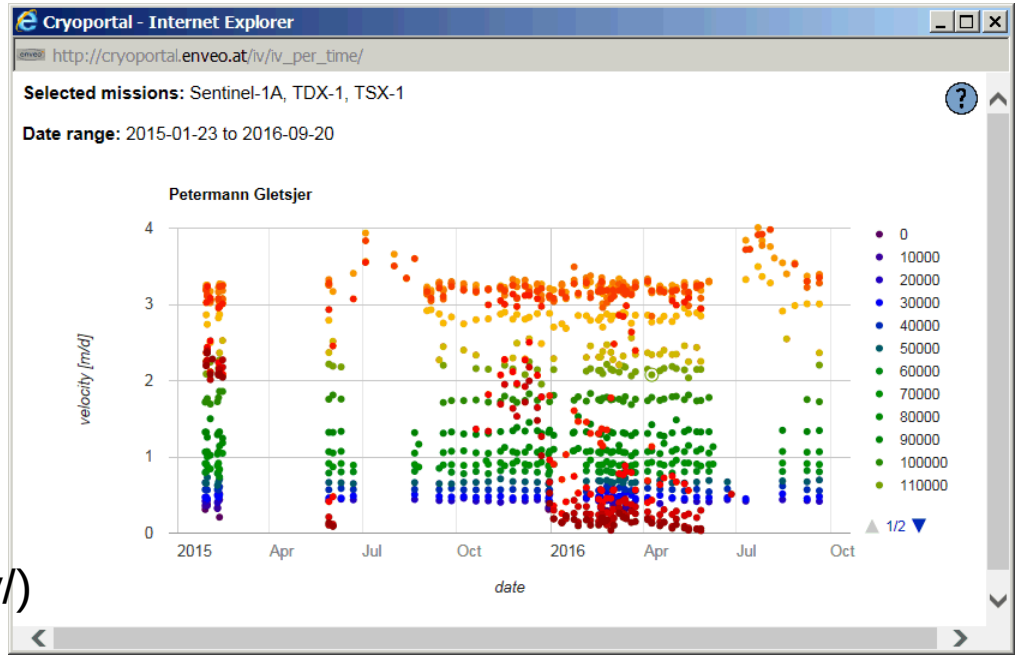


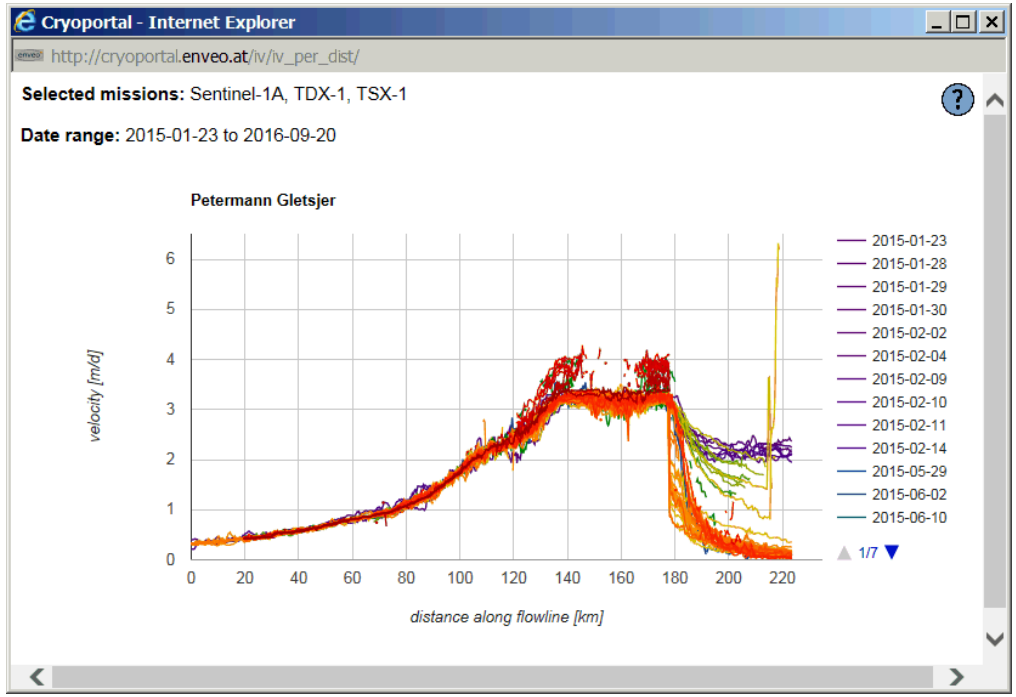
Mouginot, et al. 2015

Glacier Velocity

Petermann Glacier, Greenland
Multi-satellite velocity time series combining Sentinel-1A, TDX-1 and TSX-1
Jan 01 2015 to Sept 20 2016
ENVEO CryoPortal
http://cryoportal.enveo.at/iv/icevelocity/)

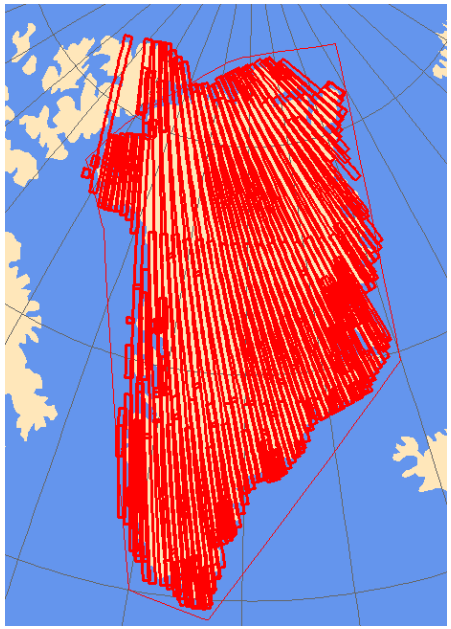




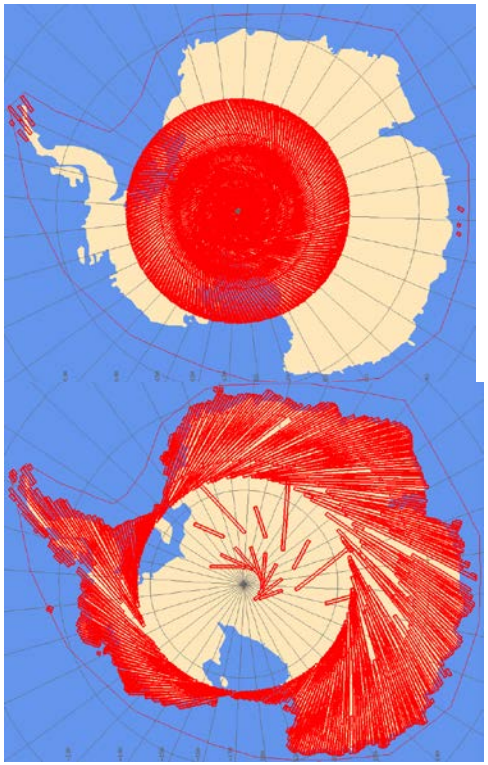


Essential Unique Contribution TanDEM-X operational acquisition

2 complete coverages in 2011 and 2012 (ascending orbits)

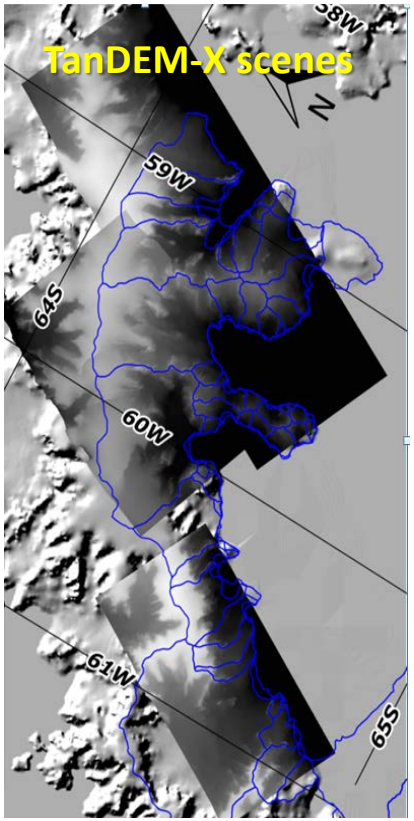


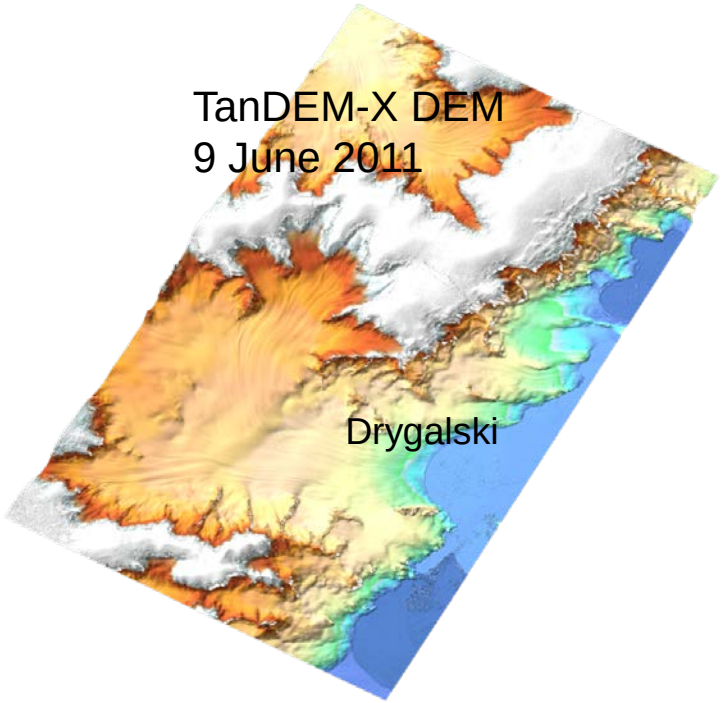
2 complete coverages 2013 and 2014 right & left looking

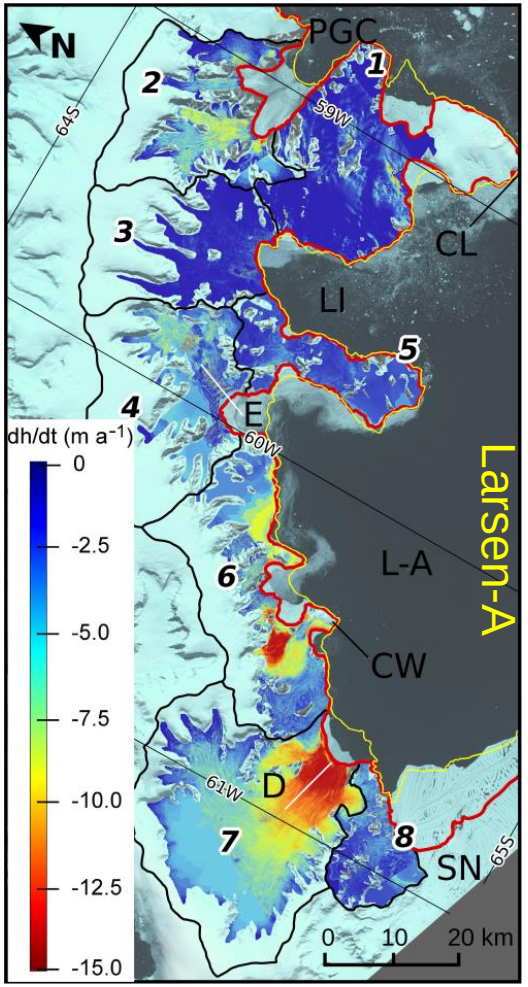


- Additional acquisitions (outlet glaciers, complex topography) for multiple baseline processing also during the science phase (2015)
- Processing of the DEMs ongoing : ITP **I**ntegrated ***T****anDEM-X* **P**rocessor + MCP (**M**osaicking and **C**alibration **P**rocessor)
- No ICESat corrections will be applied in the interior of the ice sheets
- 90 m pixel spacing DEM planned to be available by 2016 → Call for data (will be launched).

Elevation Change 2011- 2013 by TanDEM-X DEM Differencing







Issues of InSAR DEM differencing:

- vertical and horizontal coregistration
- position of the phase scatterers below the real surface

Rott et al, GRL, 2014

SAR Data Compendium

- Capturing space agency contribution initiated during the IPY
- Definitive information source regarding SAR data sets of the cryosphere acquired or processed under the auspices of the WMO PSTG
- Shows what space agencies have achieved and can achieve through coordination
- Helpful aid for the science community
- Information tool for the Policy community
- Expected release – Spring 2016

Overview of Two Decades of Coordinated Satellite SAR Data Acquisitions over Polar Regions

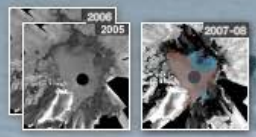
ERS-1/2 (1991–2011)
Envisat ASAR (2002–2012)
RADARSAT-1 (1995–2013)
ALOS PALSAR-1 (2006–2011)
PALSAR-2 (2014 – present)
TerraSAR-X (2007 – present)
COSMO-SkyMed (2007 – present)
Tandem-X (2008 – present)
RADARSAT-2 (2007 – present)
Sentinel-1A (2014 – present)

COOPERATION and COORDINATION

Over the past three decades, the collection of large amounts of satellite radar imagery over vast polar regions has become an outstanding example of international cooperation among space agencies and the polar science community. Building on the successful cooperation and coordination during the International Polar Year, the Polar Space Task Group has recently re-enacted the SAR Coordination Working Group. This Group provides coordination among space agencies operating SAR satellites to facilitate acquisition and distribution of fundamental SAR datasets. It also contributes to the development of data products in support of cryospheric scientific research and applications.


RADARSAT-1 Arctic Ocean, ASAP Project (CSA, NASA, 1996–2007)


RADARSAT-1 Cdn. Ice Centre archive data (CSA, EC/CIS, 1996–2013)

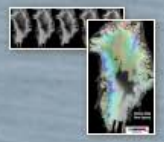


Envisat ASAR Arctic Ocean and Greenland (ESA, 2005–08)

Thematic SAR data collection for selected regions

ERS-1 SAR Greenland mosaic and DEM [Ref. 1] (ESA, NSIDC 1993)

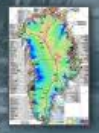
RADARSAT-1 InSAR Greenland, backscatter maps, ice velocity (CSA, 2000–01, 2005–09)



TerraSAR-X Greenland Outlet Glaciers (DLR, 2005–06)

ALOS PALSAR Greenland and Arctic Ocean (JAXA, 2008–2009)

Var. SAR sensors Greenland ice velocity [Ref. 4] (IPY, 2008/09)

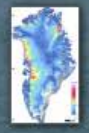


TanDEM-X Greenland InSAR map (DLR 2011–13)

RADARSAT-1 Greenland InSAR, dB map (CSA, 2013)

RADARSAT-2 Greenland InSAR (CSA, 2014)

COSMO-SkyMed Greenland (ASI, 2013/14)



Sentinel-1 Greenland ice velocity [Ref.5] (ESA, 2015)

TerraSAR-X Greenland Outlet glaciers (DLR, 2014–15)

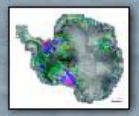
International Polar Year

1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

PSTG - SAR CWG >>>

RADARSAT-1 Antarctic Mapping Mission-1 (CSA, 1997)

RADARSAT-1 Antarctic Mapping Mission 2 (CSA, 2000)



Ice Flow Dynamics and Mass Balance, various sources, [Ref. 2]

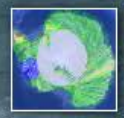
RADARSAT-2. dual-pol Antarctic Mapping Mission (CSA, MDA. 2007)

ALOS PALSAR Antarctica & Southern Ocean (JAXA 2008–09)

Envisat ASAR Southern Ocean Ice (ESA, 2010)

TerraSAR-X InSAR Mapping Antarctica Glaciers (DLR, 2008–13)

TanDEMX Antarctica Mapping Mission DLR, 2013–2014

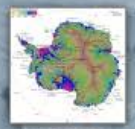


RADARSAT-2 Antarctica InSAR (CSA, MDA, 2013)

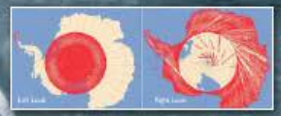
RADARSAT-2 Antarctica InSAR (CSA, MDA, 2014)

ALOS PALSAR-2 SAR Global mapping, incl. polar regions, (JAXA, t.b.d.)

Envisat ASAR GMM Antarctica (ESA 2004)



Antarctica Ice Flow Products [Ref. 3]



COSMO-SkyMed Antarctic regions (ASI, 2013–2016)

Polar imaging activities and polar interests are common to several space agencies in support of their policy mandate, science priorities, and science community requirements. Coordinated activities can be highly beneficial. Over the next years, they will continue to provide multi-frequency observations over polar regions. These coordinated activities will ensure high-frequency of revisit in the case of coherent and interoperable datasets from various missions, and they will strive for workload distribution across agencies – consistent with mission constraints and capabilities.

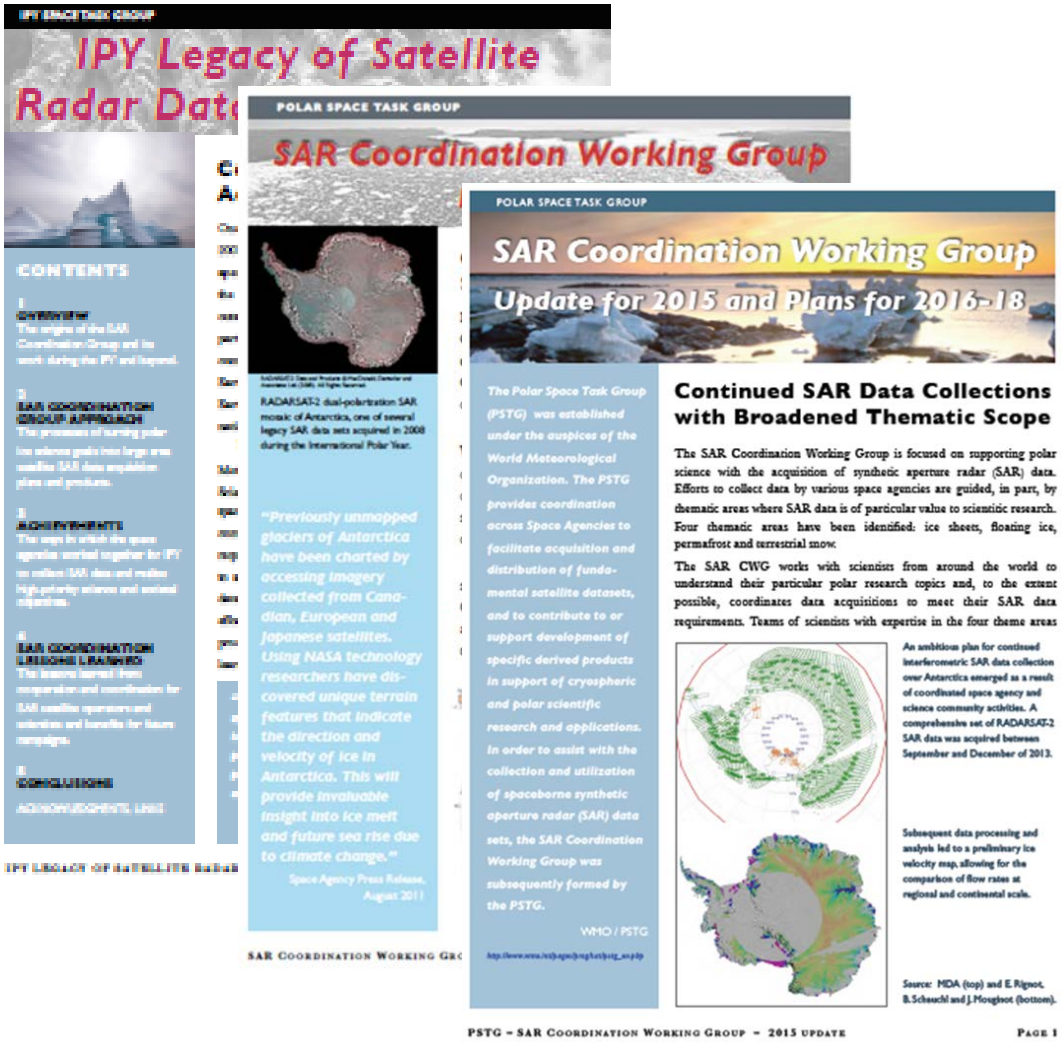
REFERENCES:
[Ref. 1] Fahnestock et al. 1997
[Ref. 2] Rignot et al. 2006
[Ref. 3] Rignot et al. 2011
[Ref. 4] Rignot & Mouginot 2012
[Ref. 5] Nagler et al. 2015

NOTE:
This graphic was prepared on behalf of the Polar Space Task Group's SAR Coordination Working Group. The contributions and advice received from the working group members is gratefully acknowledged. The summary information presented here is not exhaustive; it reflects the status of plans and actual SAR data collections as of 2015.
For further information: http://www.wmo.int/pages/prog/sat/pstg-sarcwg_en.php

Concept & design: D. Weale (2015)

esa DLR JAXA Norsk Romsenter NASA

SAR Coordination WG Brochures



- IPY Space Task Group SAR Legacy brochure - 2010
- Plans and Update – 2013
- Plans and Update – 2015
- High level communication tool
- Focus on achievements
- Includes update from the thematic science groups
- To be circulated in events, conferences, workshops, used as an information tool for internal communication, etc.

Conclusion

- Earth observation satellites can provide diversified, repeatable, reliable, continuous, and sustained observations of the entire polar regions.
- Through the Polar Space Task Group (PSTG), demonstration of space agencies commitments towards supporting the key science questions and related monitoring needs.
- Coordination among space agencies is critical to meeting the broad set of requirements.
- The PSTG strives to maintain an open dialogue between the science community and space agencies in order to put the “best minds” at work using the best technology assets possible.