

Utilization of a virtual SAR constellation for ice sheet monitoring

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Thirty years of glacier grounding line retreat in Antarctica

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Significant Outcome:

The Antarctic ice sheet lost $12,820 \pm 1,873 \text{ km}^2$ of grounded ice between 1996 and 2025 ($442 \pm 64 \text{ km}^2/\text{year}$).

3/4 of the coastline is stable. 1/4 of the coastline retreated in:

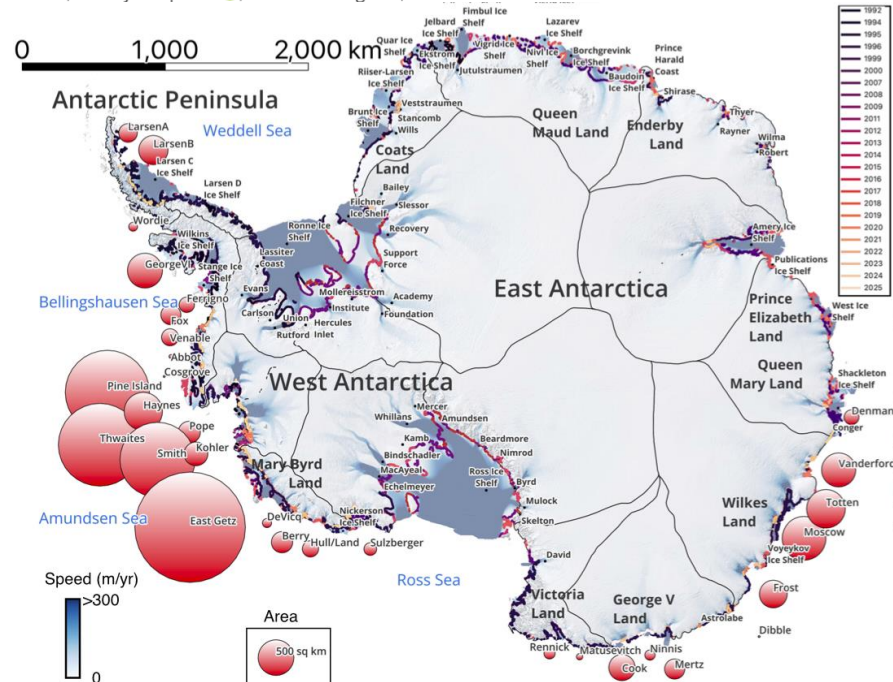
- Antarctic Peninsula (Larsen A-B, George VI)
- Wilkes and George V Lands, East Antarctica
- Especially Amundsen and Getz sectors of West Antarctica.

Supporting NASA Programs:

- MEaSUREs (grounding line product generation)
- CSDA (commercial SAR data for fast moving glaciers)

Data Sources (a virtual constellation):

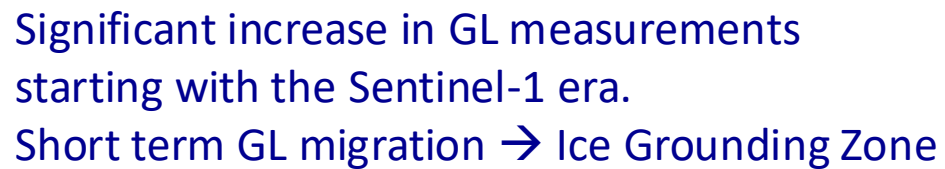
ESA's ERS-1, ERS-2, ENVISAT ASAR, Copernicus SENTINEL-1, CSA's RADARSAT-1, RADARSAT-2, RCM, JAXA's ALOS PALSAR, ALOS-2 PALSAR-2, SAOCOM, ASI's Cosmo SkyMed, DLR's TerraSAR-X, ICEYE US (commercial), ICEYE OY, AIRBUS US (commercial).



NASA Measures ESDR:

GL (<https://nsidc.org/data/nsidc-0498/versions/2>)

GZ (<https://nsidc.org/data/nsidc-0778/versions/1>)





Coordination -> Responsible Use

SENTINEL-1

C-band
6-day / 12-day
(1-day(!) in 2026)
Coastal Antarctica
Free and open

RCM

C-band
4-day (/8 /12)
Background
campaign.
Free following
registration

ICEYE

X-band
1-day
Daily (!)
observations.
NASA 3rd party
purchase

Very soon:

NISAR

L-band, left looking
12-day

Antarctica-wide coverage ASC+DSC

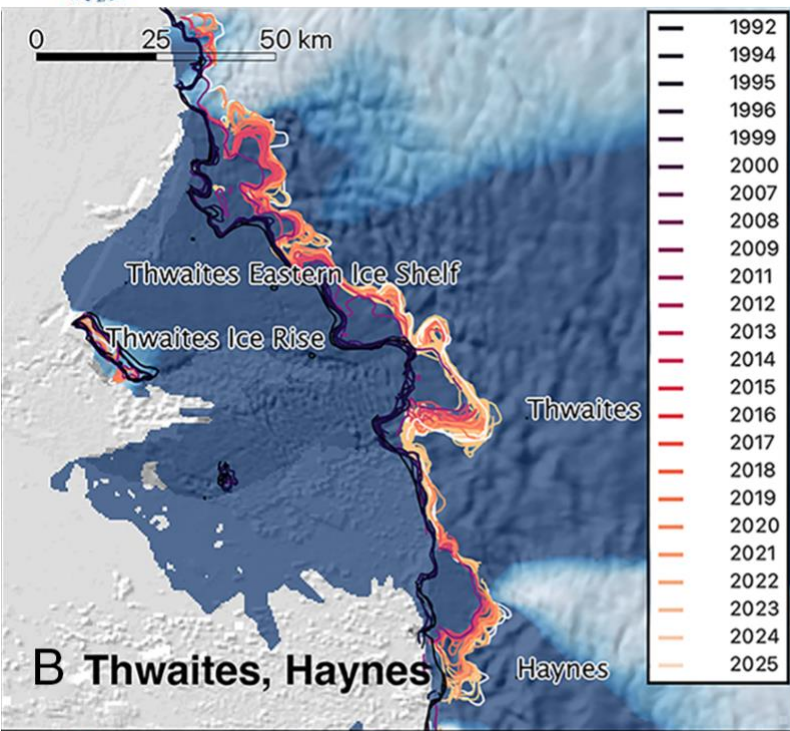
Free and open access; Level-2 products

RCM & ICEYE:

Focus on GL area of fast glaciers.

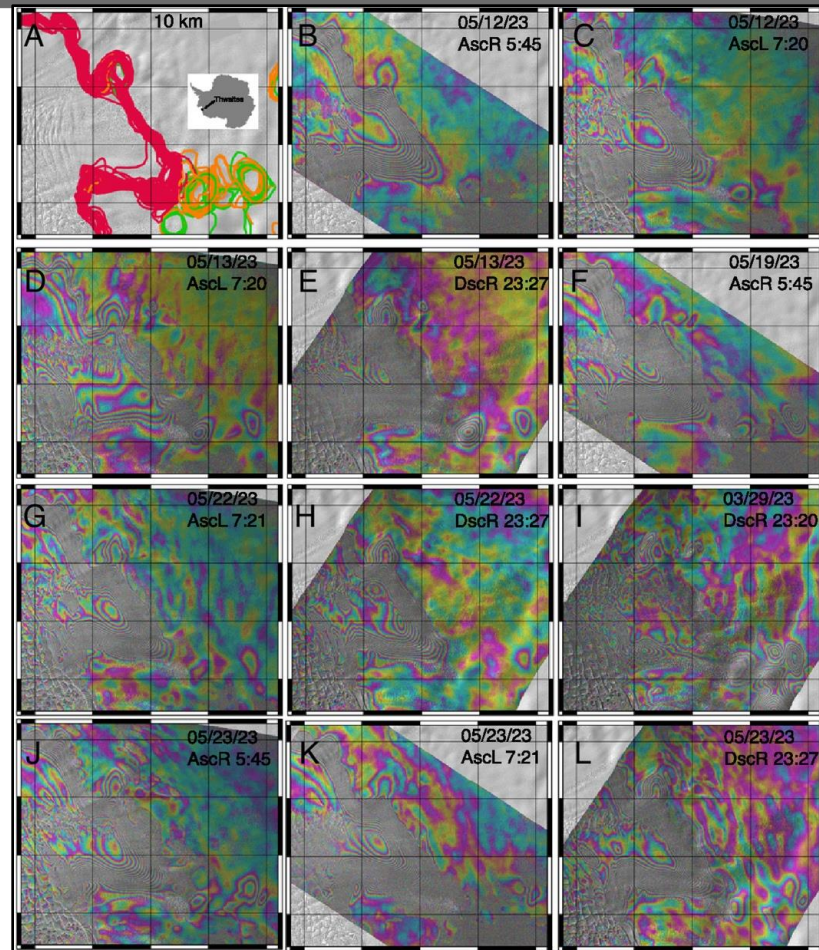
- Small geographic coverage
- High science impact

Thwaites Glacier



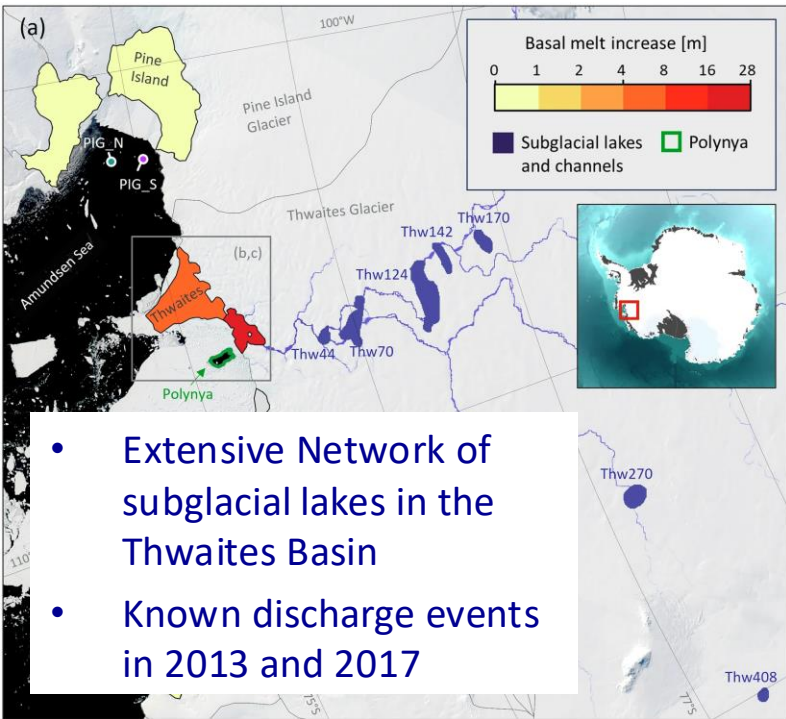
Using InSAR:
(2023 Time series)
Seawater intrusion
upstream of
the grounding line.

ALSO:
Evidence of
subglacial
meltwater
making its way
downstream



Rignot et al. 2024. Widespread Seawater intrusions beneath the grounded ice of Thwaites Glacier, West Antarctica. *PNAS*

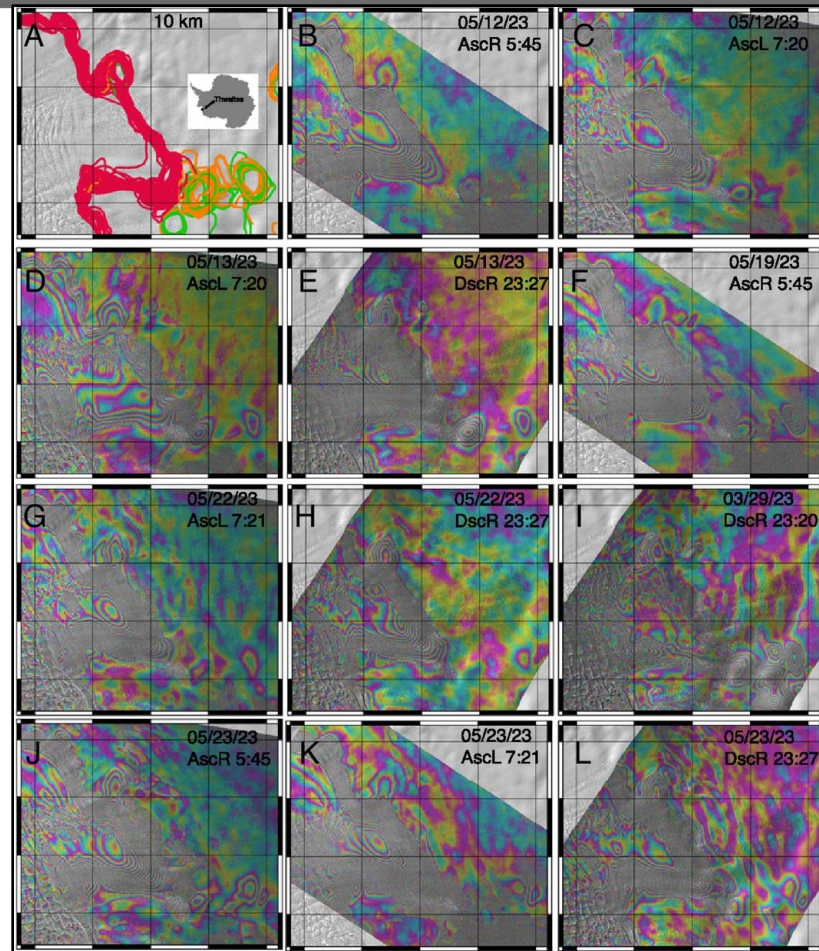
Thwaites Glacier



- Extensive Network of subglacial lakes in the Thwaites Basin
- Known discharge events in 2013 and 2017

Using InSAR:
(2023 Time series)
Seawater intrusion
upstream of
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01/08-01/09-01/10

Thwaites Glacier

Grounded ice

TU93

THW70

Mapped
subglacial
lakes

THW124

Ice Shelf
(floating)

Ice Grounding Zone

ICEYE Coverage

Flow direction

0 25 50 km



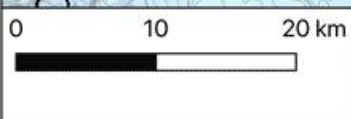
ICEYE

Daily
observations
Animation:
Range offset
double
difference to
Next
neighbor.

Duration:
12/30 -1/16

Anomaly
01/05
to
01/11

Uplift **Subsidence**





NISAR

- L-band, 12-day repeat orbit
- Double difference interferograms generated based on level-2 data (specifically, the interferogram layer in GUNW)
- Commissioning phase data – uncalibrated
- The AOI is a low backscatter area

First available acquisition for the area: Nov 5, 2026

NISAR

11/05-11/17-11/29

11/17-11/29-12/11

11/29-12/11-12/23

12/11-12/23-01/04

12/23-01/04-01/16

01/04-01/16-01/28

01/16-01/28-02/09

01/28-02/09-02/21

02/09-02/21-03/05

02/21-03/05-03/17

03/05-03/17-03/29

TU93

THW70

THW124

0

25

50 km



Sentinel-1

- C-band, 1-day repeat orbit campaign
(limited special campaign during S1d commissioning).
- First available acquisition for the area of interest: Jan 9
- Phantastic campaign for grounding line measurements!

Sentinel-1

01/09-01/10

01/21-01/22

01/21-01/22

02/02-02/03

02/02-02/03

02/14-02/15

02/14-02/15

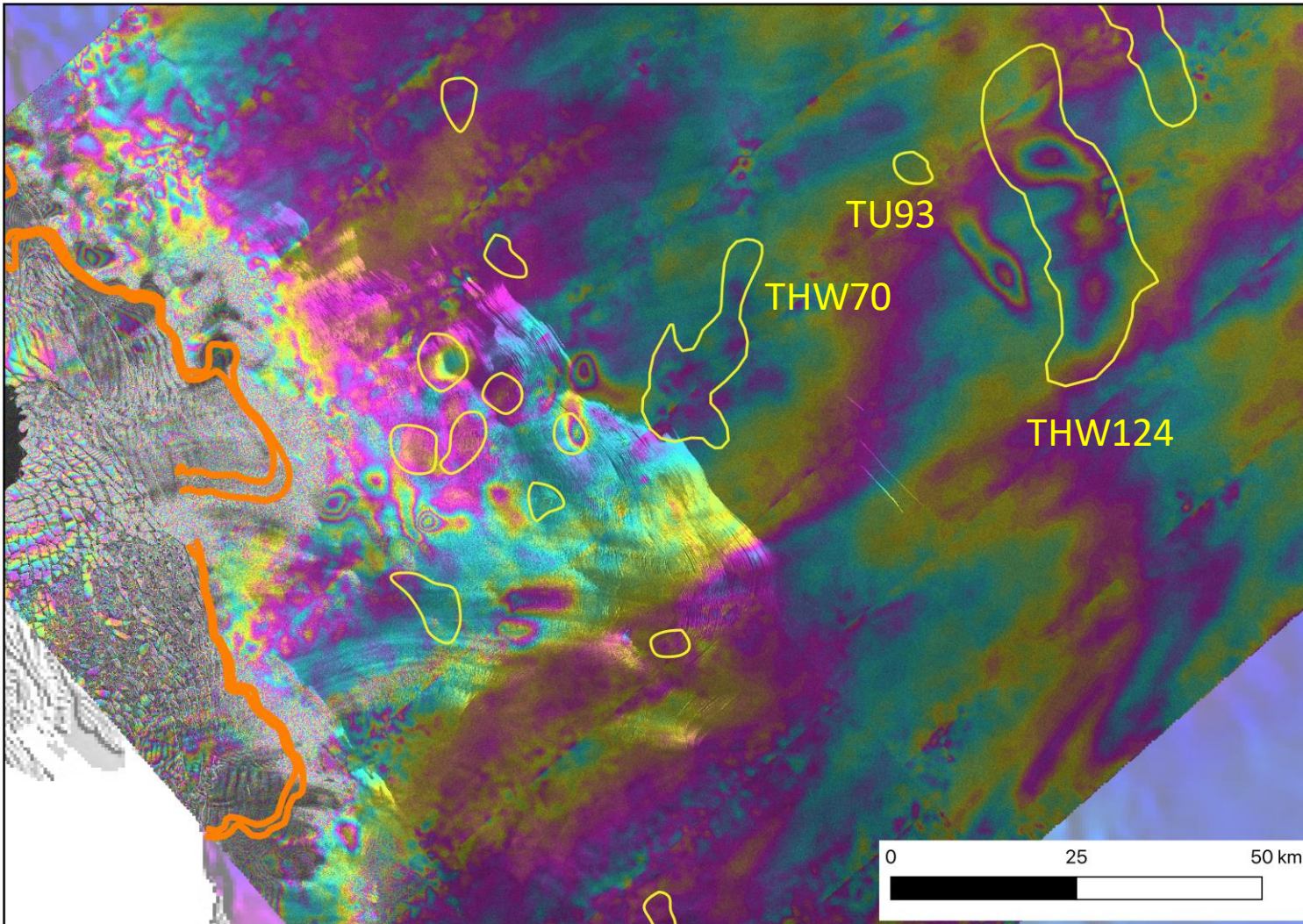
02/26-02/27

02/26-02/27

03/10-03/11

03/10-03/11

03/22-03/23



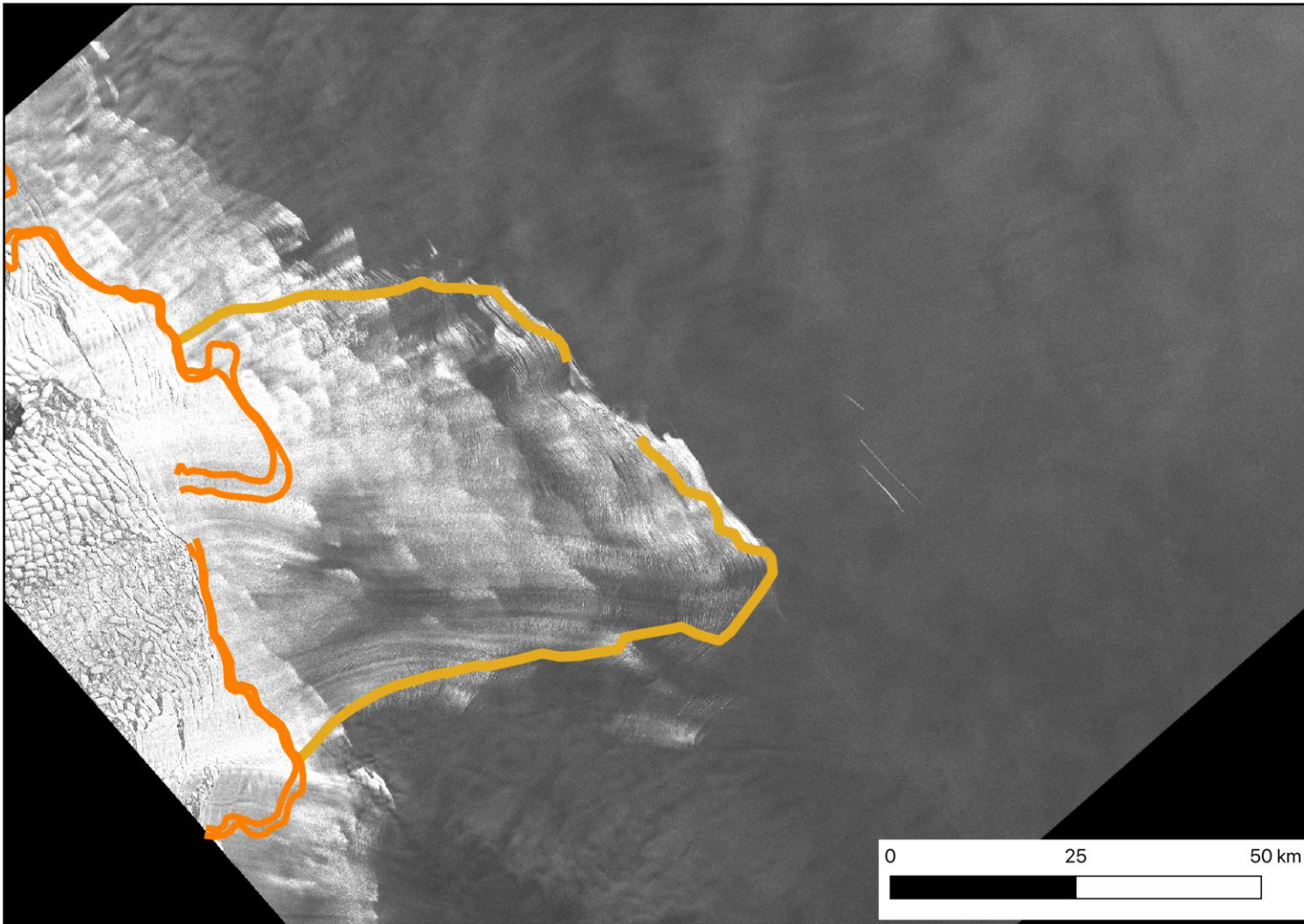
Sentinel-1

01/09-01/10

01/21-01/22

Evidence of
glacier speed
response

This response
appears
temporary in
nature and
confined to
the highly
crevassed
area





What do we see?

- Using ICEYE daily observations, we witnessed a large release of subglacial melt water starting Jan 5 and lasting until Jan 11, 2026, with some residual activity after that. Water moves rapidly, something that has not been observed before in Antarctica.
- NISAR observations cover a larger geographic area and show that Lake THW170 started draining in late November / Early December, thereby triggering the chain of events. No lakes further upstream appear to be involved.
- Sentinel-1 1-day campaign data also captured the event and cover a larger area compared to ICEYE, but 1-day repeat is only available every 12 days. There is evidence for a spatially and temporally limited speed increase of Thwaites main trunk in response to the subglacial water release.



A Virtual Interagency Constellation

- Combining results from **all available** missions using their individual strengths.
- No single mission can match the information content of the constellation.
- Commercial SAR data can be used to augment space agency missions and provide new information.
- While not formally coordinated following the hiatus of PSTG, our recommendations to agencies are based on results and experiences during **PSTG science coordination** work as well as on our MEaSUREs project results.
- Coordination enables the **responsible use of assets**. Formal efforts are underway from WMO as well as from CEOS. **Make sure to coordinate the coordinators!**



Thank you!

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ESDR record

Ice Velocities:

<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>

<https://nsidc.org/data/NSIDC-0761>

Grounding Line:

<https://nsidc.org/data/NSIDC-0498>

Grounding Zone:

<https://nsidc.org/data/NSIDC-0778>

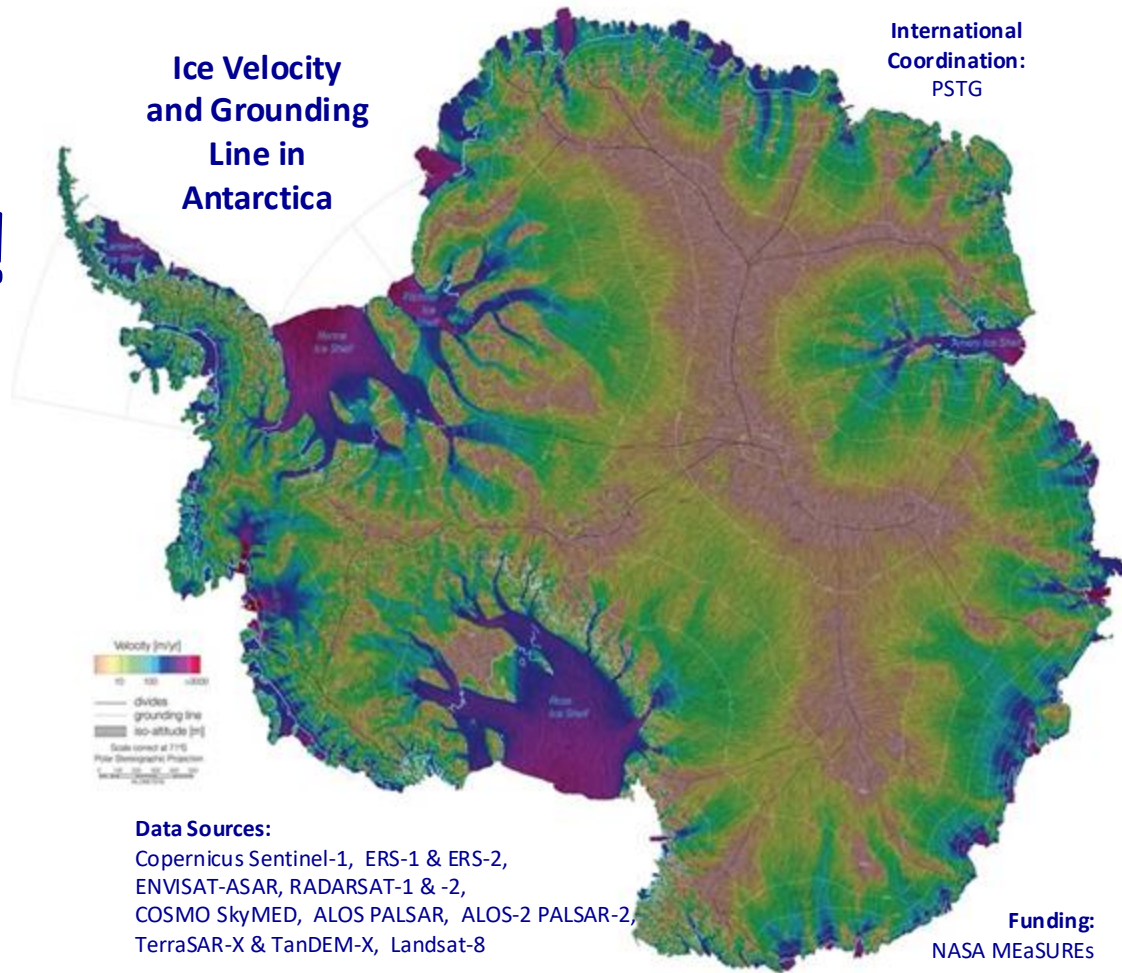
Boundaries:

<https://nsidc.org/data/NSIDC-0709>

Bedmachine Antarctica:

<https://nsidc.org/data/NSIDC-0756>

Ice Velocity and Grounding Line in Antarctica



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

International
Coordination:
PSTG



Funding:
NASA MEaSUREs