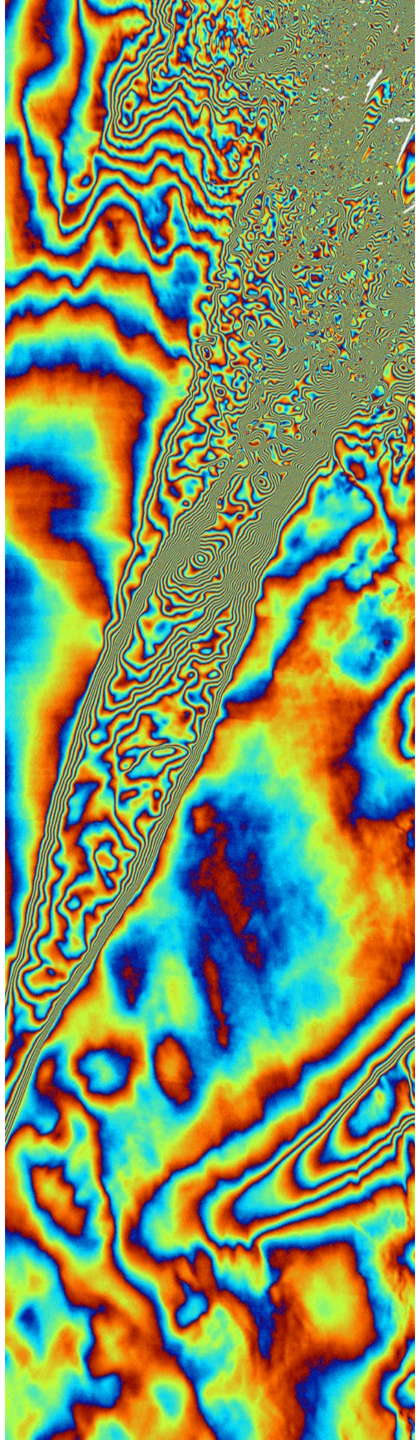


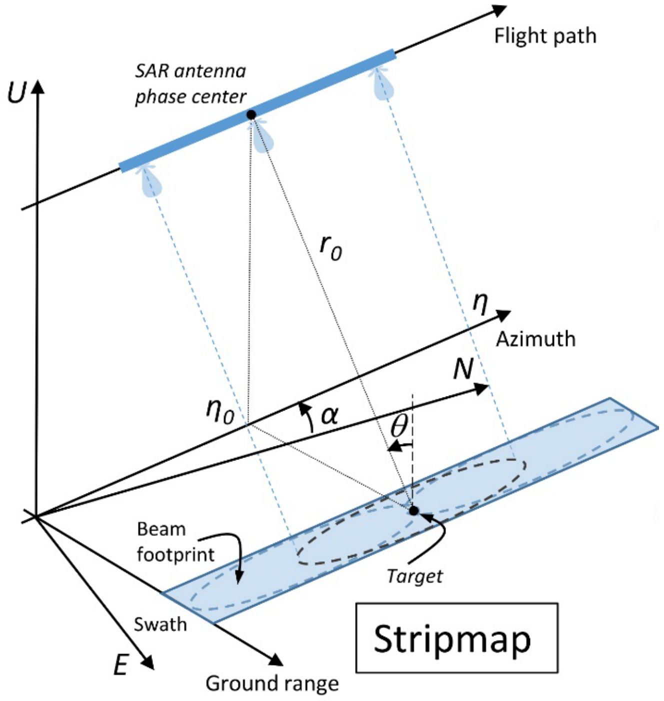
Phase-based Sentinel-1 Ice Velocity (PHAB-IV)

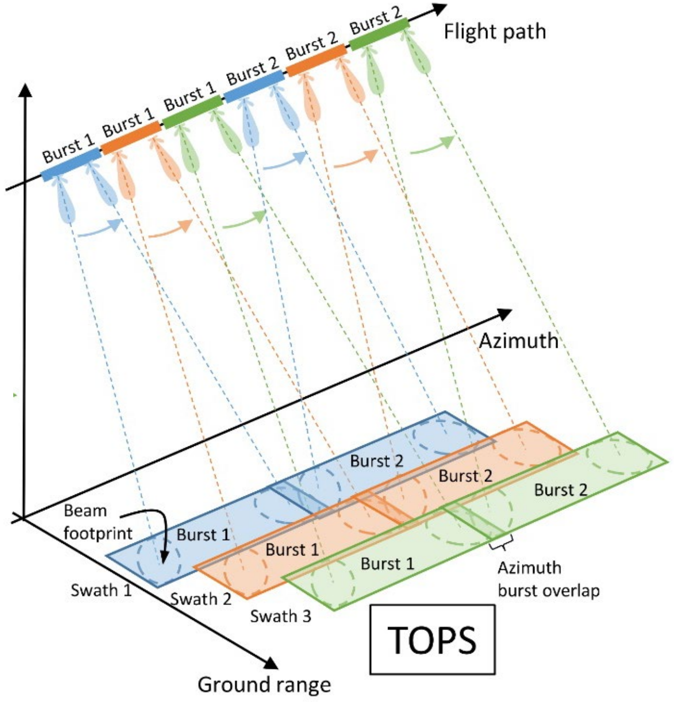
ESA Polar Science Cluster Collocation Meeting

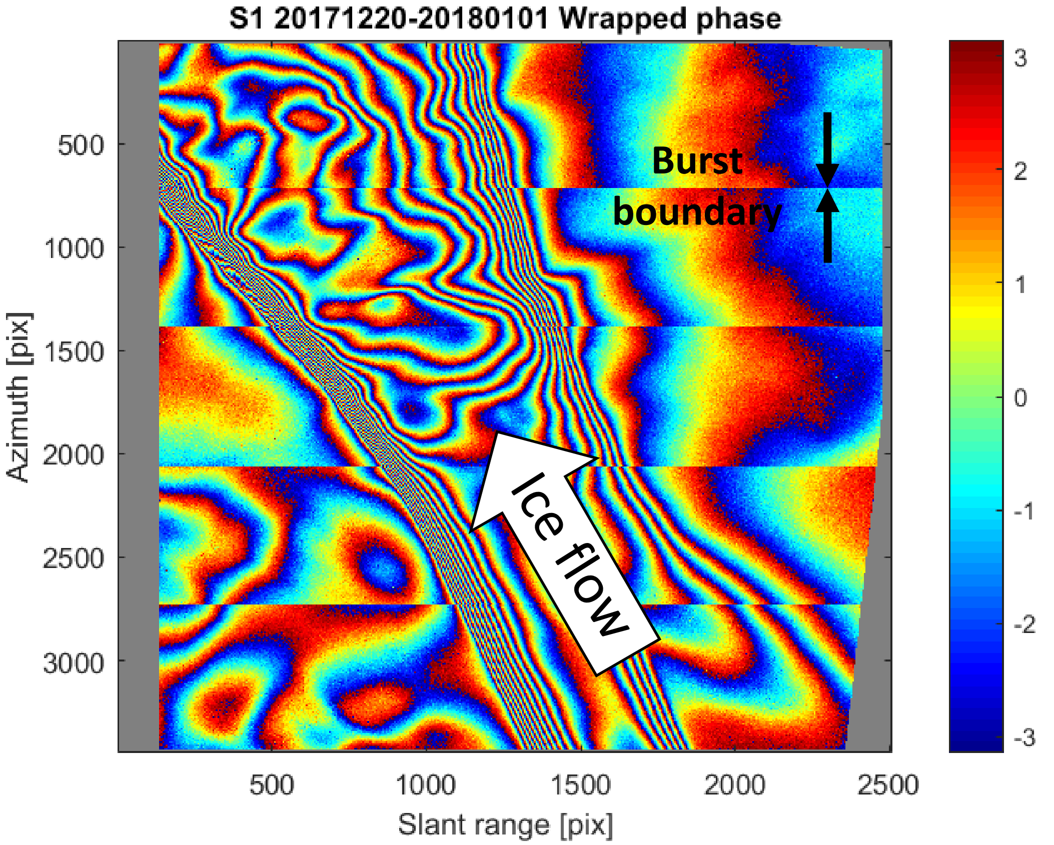
15 – 17 September 2021

J.P. Merryman-Boncori, A. Kusk, J.K. Andersen, A. Solgaard, L. Libert, T. Nagler, M. Engdahl

Motivation: a technical challenge to solve







$$\Delta\phi = \Delta\phi_r + \Delta\phi_a = -\frac{4\pi}{\lambda} v_r \Delta T + 2\pi f_{DC} \Delta\eta$$

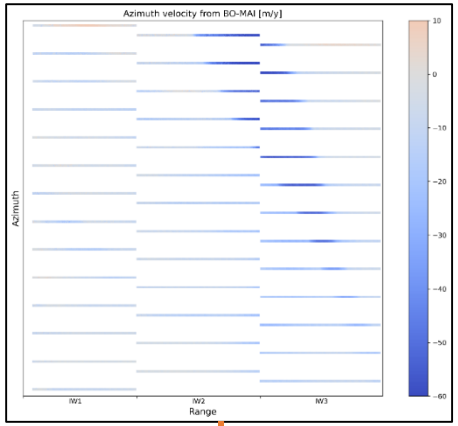
DInSAR pixel phase

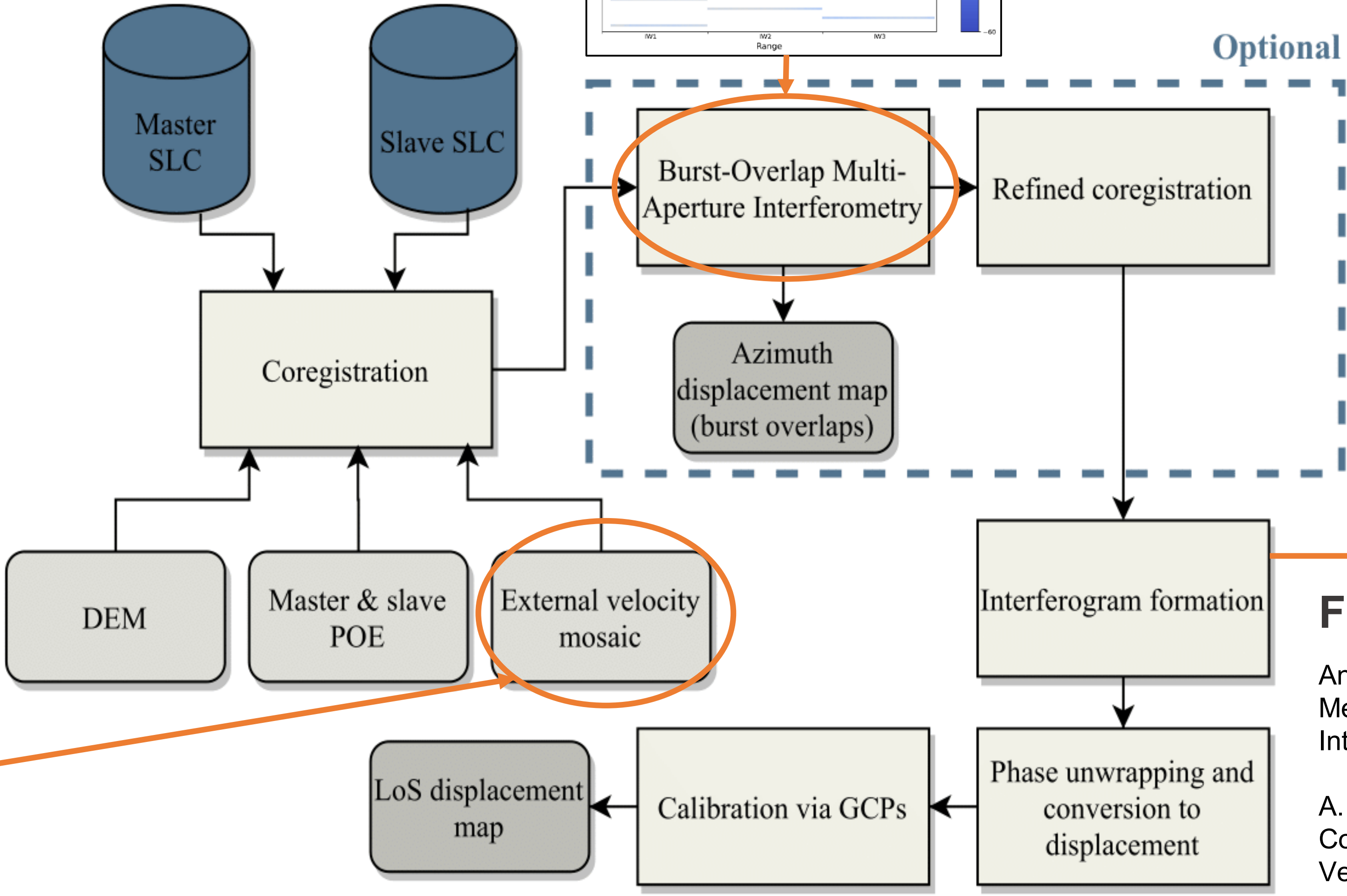
Range term (parallel to r_0)

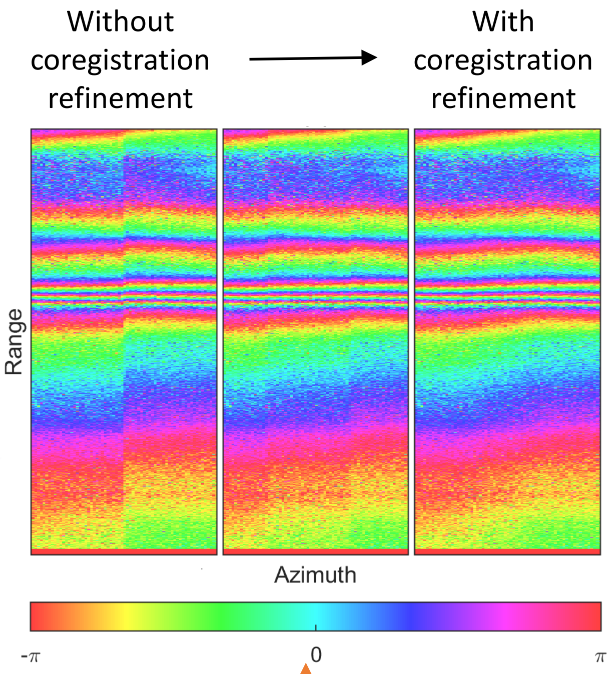
Azimuth term (parallel to flight path)

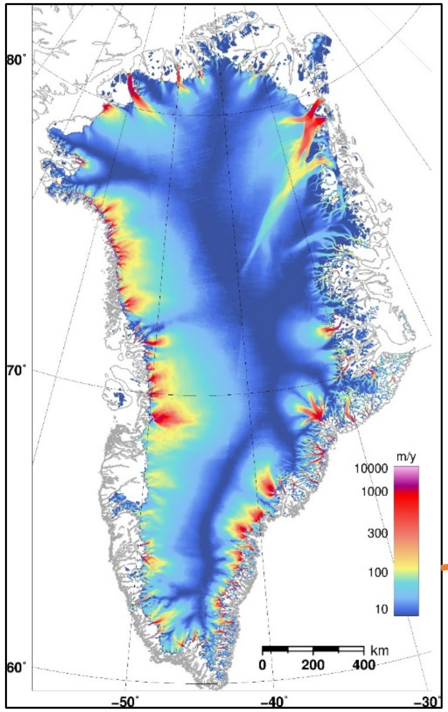
$$\Delta\eta = \Delta\eta_{motion} + \Delta\eta_{orb} + \Delta\eta_{iono}$$

DInSAR algorithm









Further described in:

Andersen et al., (2020), Improved Ice Velocity Measurements with Sentinel-1 TOPS Interferometry. *Remote Sensing.*

A. Kusk et al., (2021), Burst Overlap Coregistration for Sentinel-1 TOPS DInSAR Ice Velocity Measurements, *IEEE GRSL.*

Application to Zwally 2.1 drainage basin

Sentinel-1

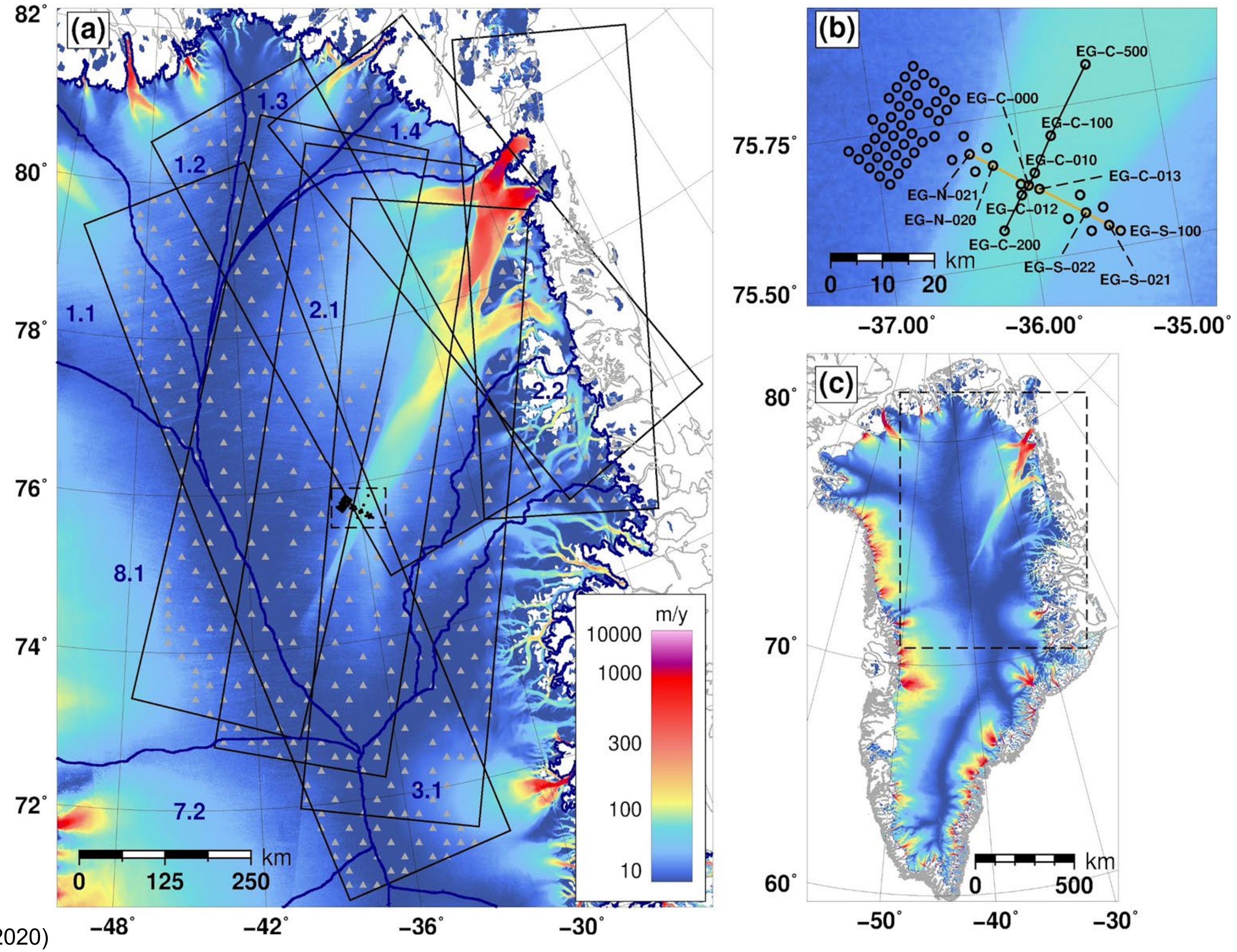
- ➢ 3 acquisition cycles (16 Dec 2019 - 25 Jan 2020)
- ➢ 4 descending + 3 ascending tracks

EastGRIP GPS

- ➢ Measurements from 2015 - 2019 [*]
- ➢ Courtesy of C. Hvidberg and A. Grinsted, Niels Bohr Institute, KU

PROMICE

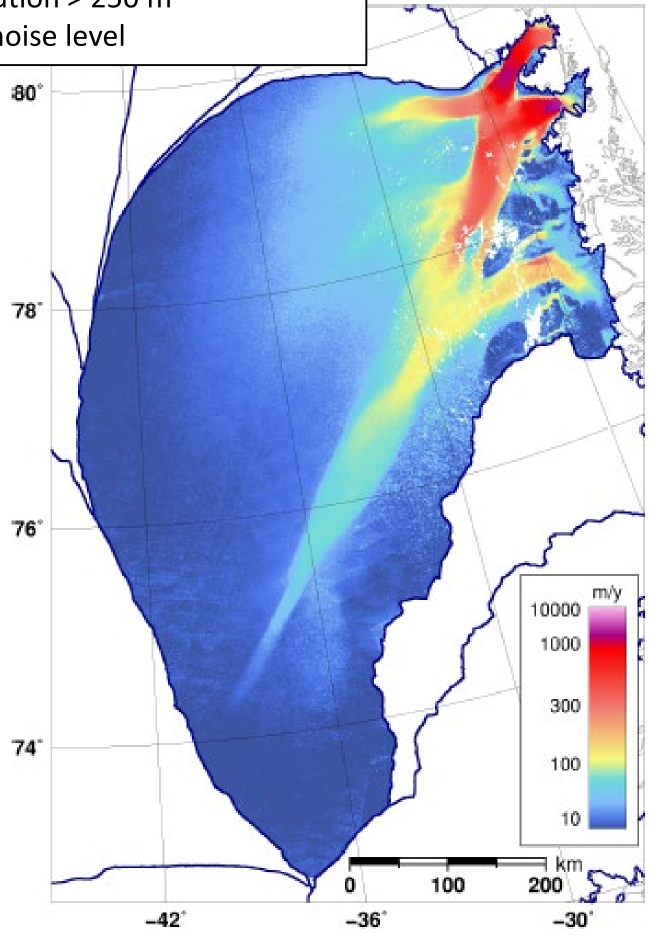
- ➢ Multi-year velocity mosaic from Sentinel-1 offset tracking (2016 - 2019)
- ➢ Generated through PROMICE



[*] Hvidberg et al. Surface velocity of the Northeast Greenland Ice Stream (NEGIS): Assessment of interior velocities derived from satellite data by GPS. *The Cryosphere*. (2020)

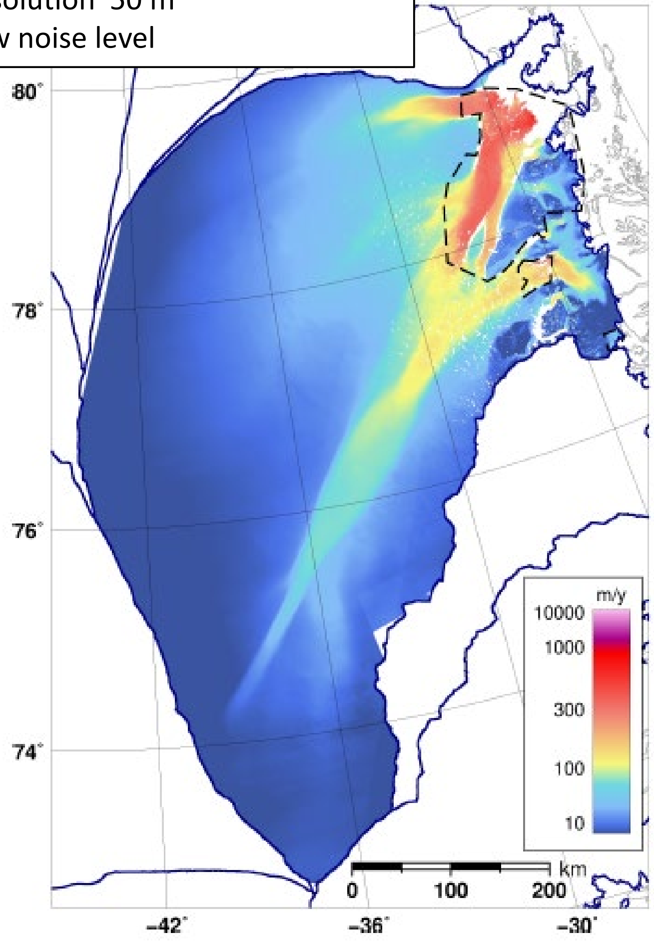
DInSAR and Offset Tracking integration

+ Good coverage of outlet glaciers
- Resolution > 250 m
- High noise level



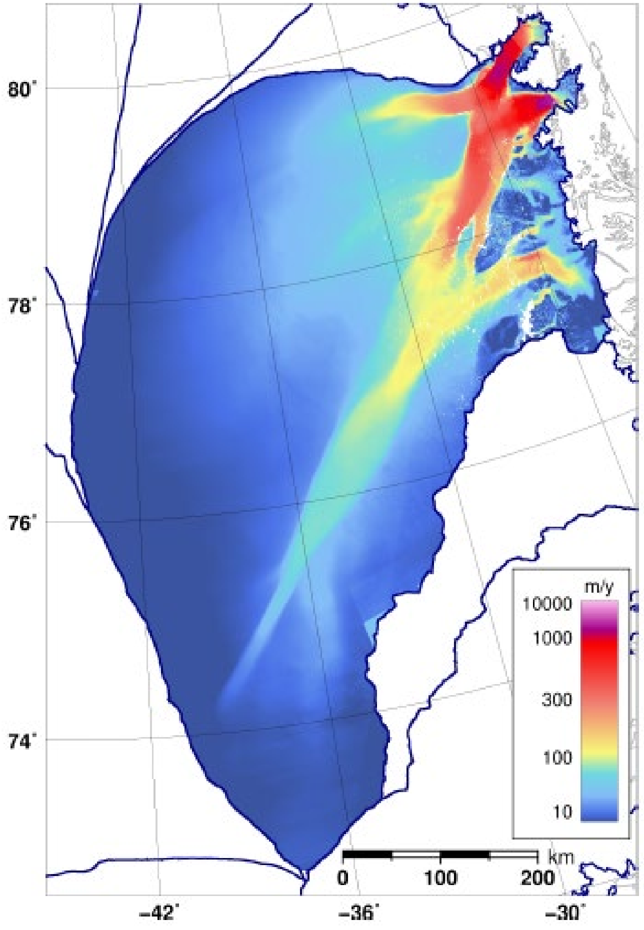
Offset tracking alone

- Poor coverage of outlet glaciers
+ Resolution 50 m
+ Low noise level



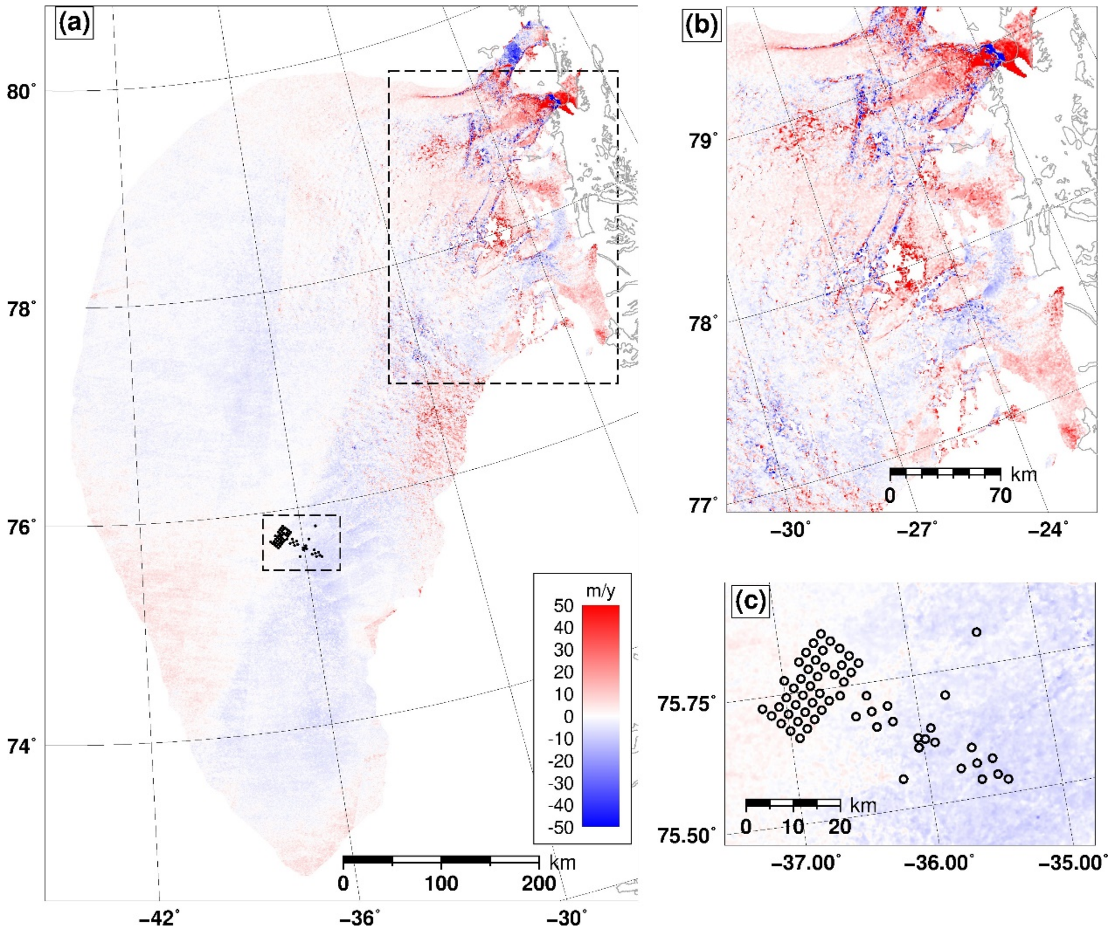
DInSAR alone

Product available at:
https://doi.org/10.11583/DTU.12865709

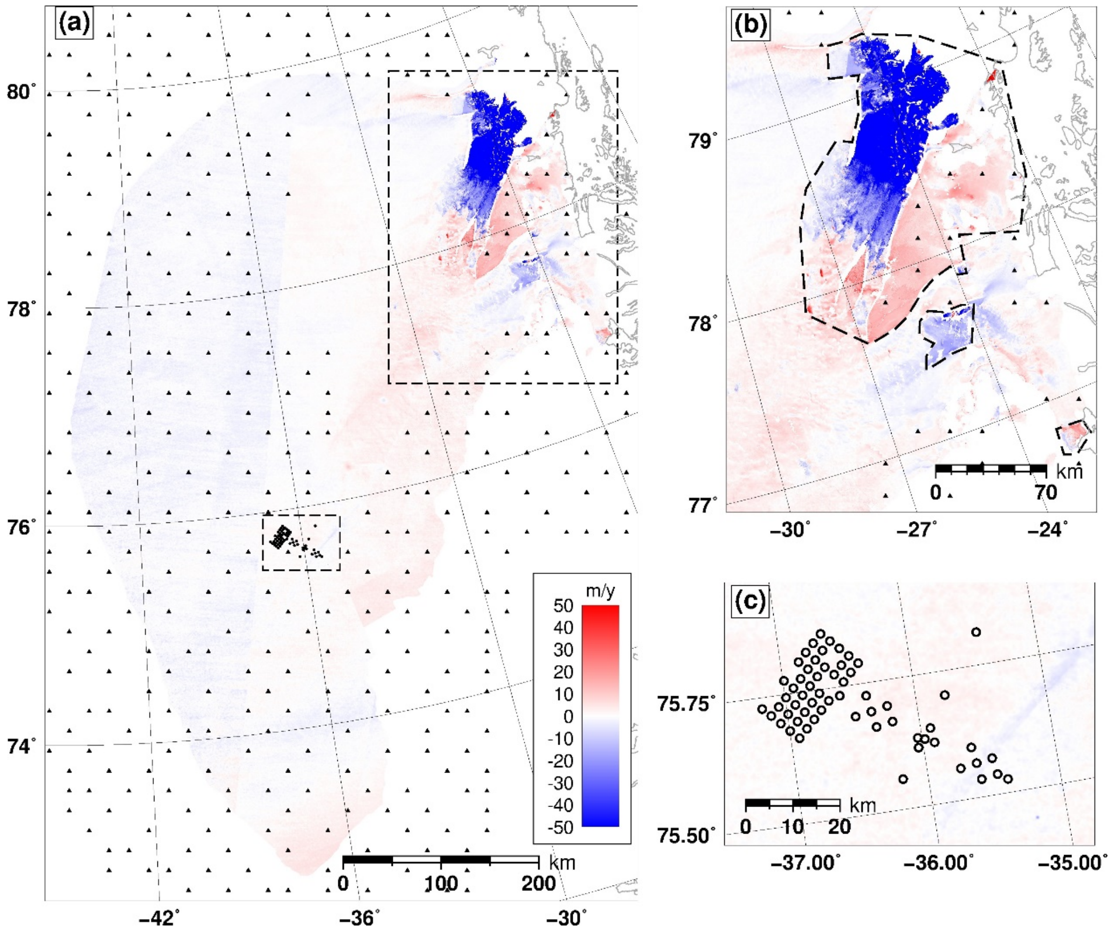


Offset tracking + DInSAR

Screening of DInSAR phase unwrapping errors

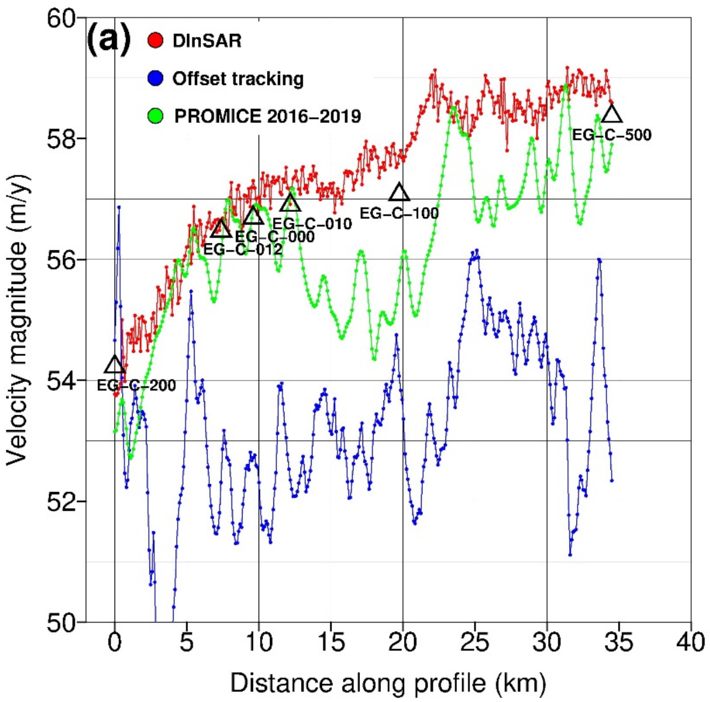


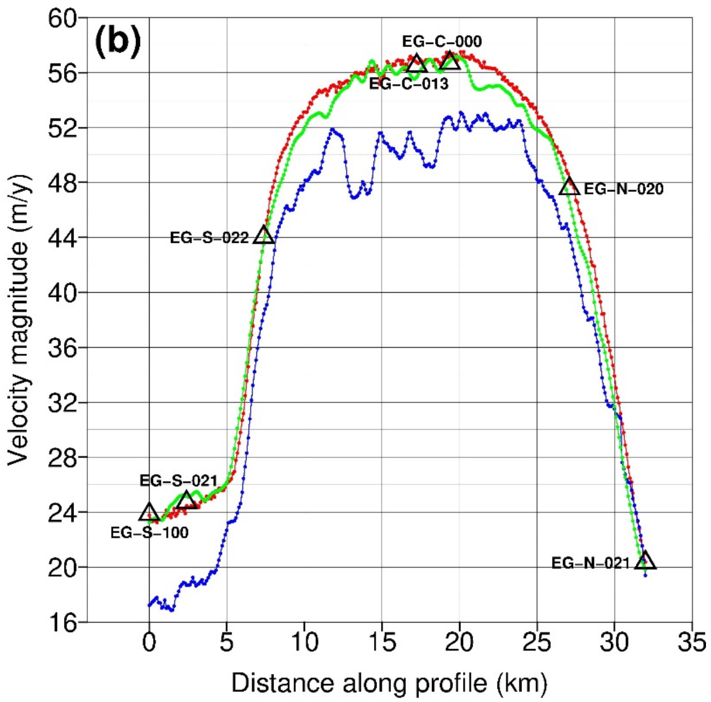
OT (40 days) – multiyear OT velocity magnitude

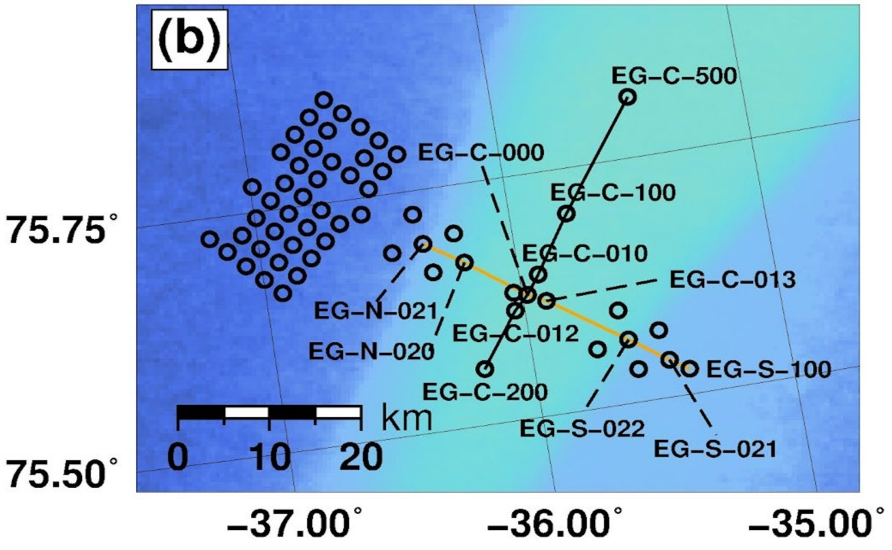


DInSAR (40 days) – multiyear OT velocity magnitude

Comparison with EastGRIP GPS



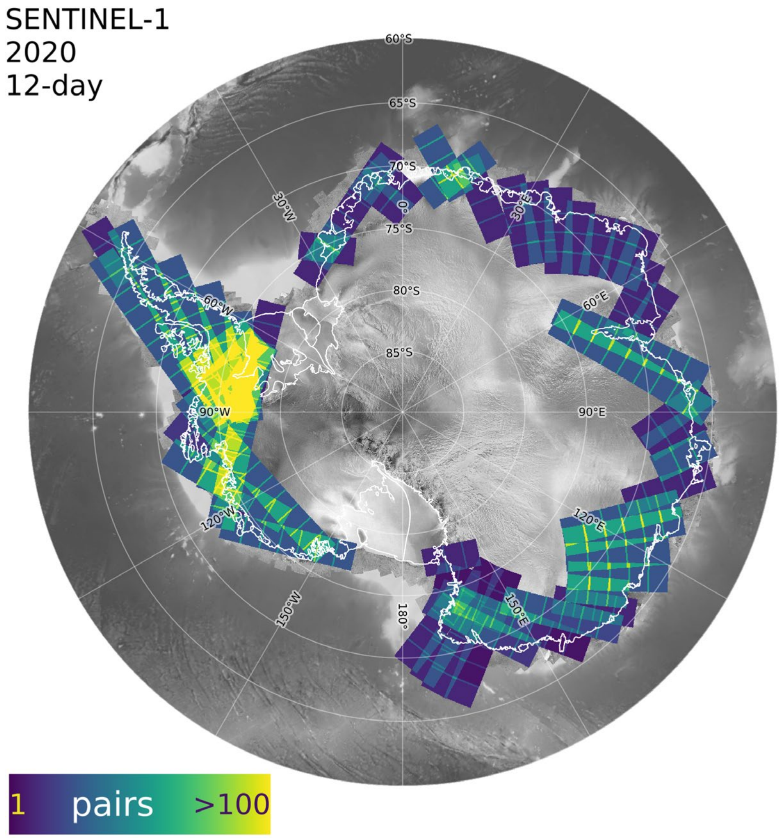




Method	Δv_x mean	Δv_x std.	Δv_y mean	Δv_y std.
PROMICE 2016-2019	-0.51	0.31	-0.83	0.74
Offset tracking (range/azimuth)	2.80	0.80	-5.22	2.31
DInSAR + offset tracking (range/azimuth)	0.02	0.18	-0.47	0.44

Towards ice sheet wide ice velocity products with InSAR and OT

<u>Antarctica:</u>
Continuous coverage of ice sheet boundaries with 6 day or 12 day repeat coverage using Sentinel-1A and 1B, acquired in IW Mode

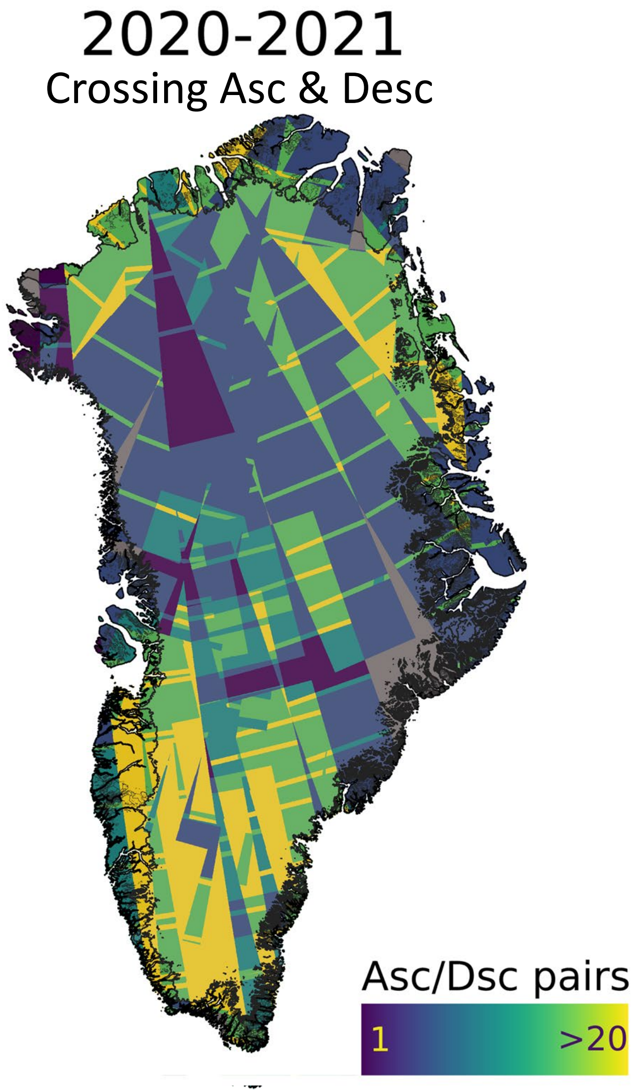


<u>Greenland:</u>
Continuous coverage of Margins using 6 tracks, IW mode:

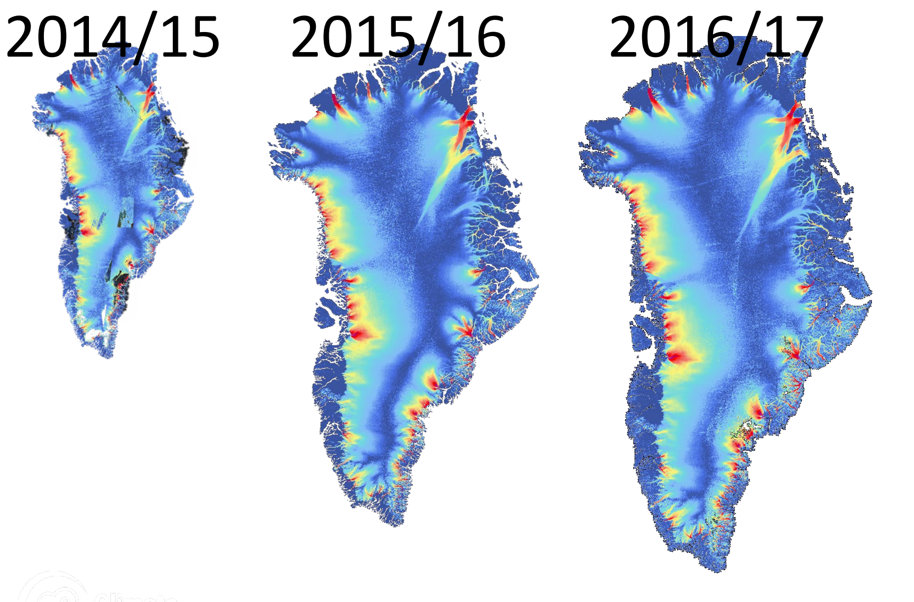
- 12 / 6 days repeat since 2014 / 2016 S1A 6 days

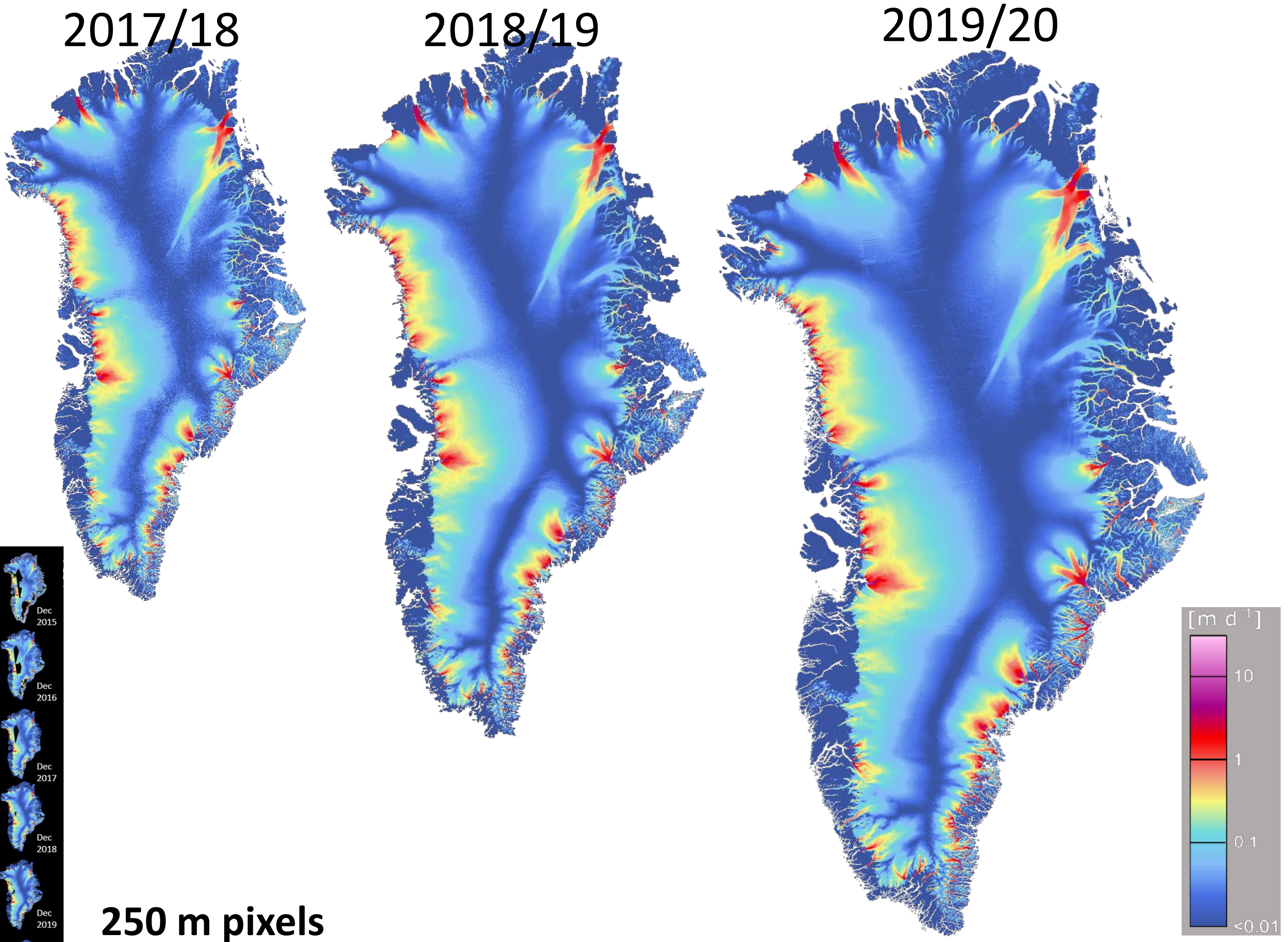
Annual Campaigns with full ice sheet wide coverage Jan – Feb.

- Since 2014/2015
- 2020/2021: almost full coverage with Crossing Orbits for InSAR IV retrieval

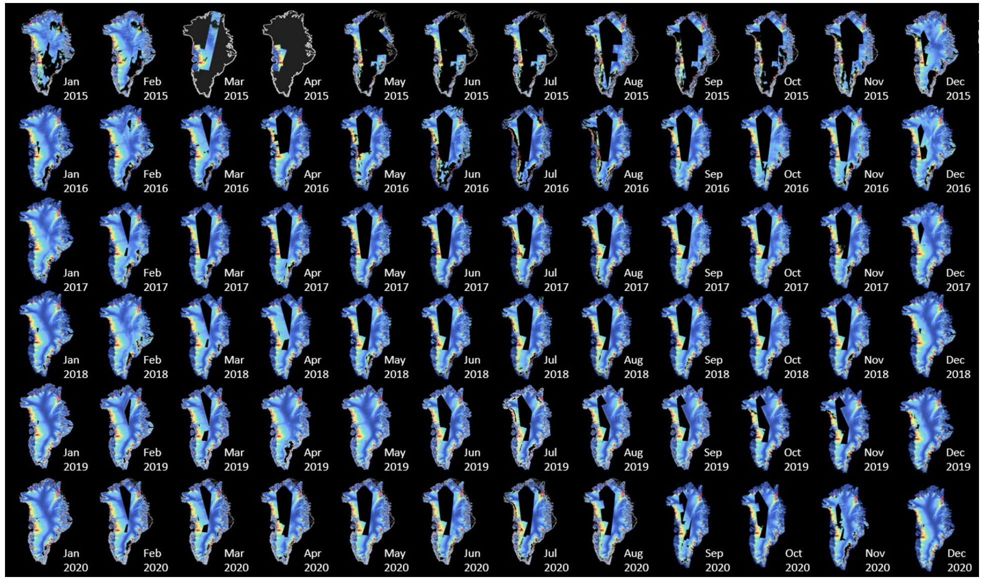


Operational Greenland Annual Ice Sheet Velocities





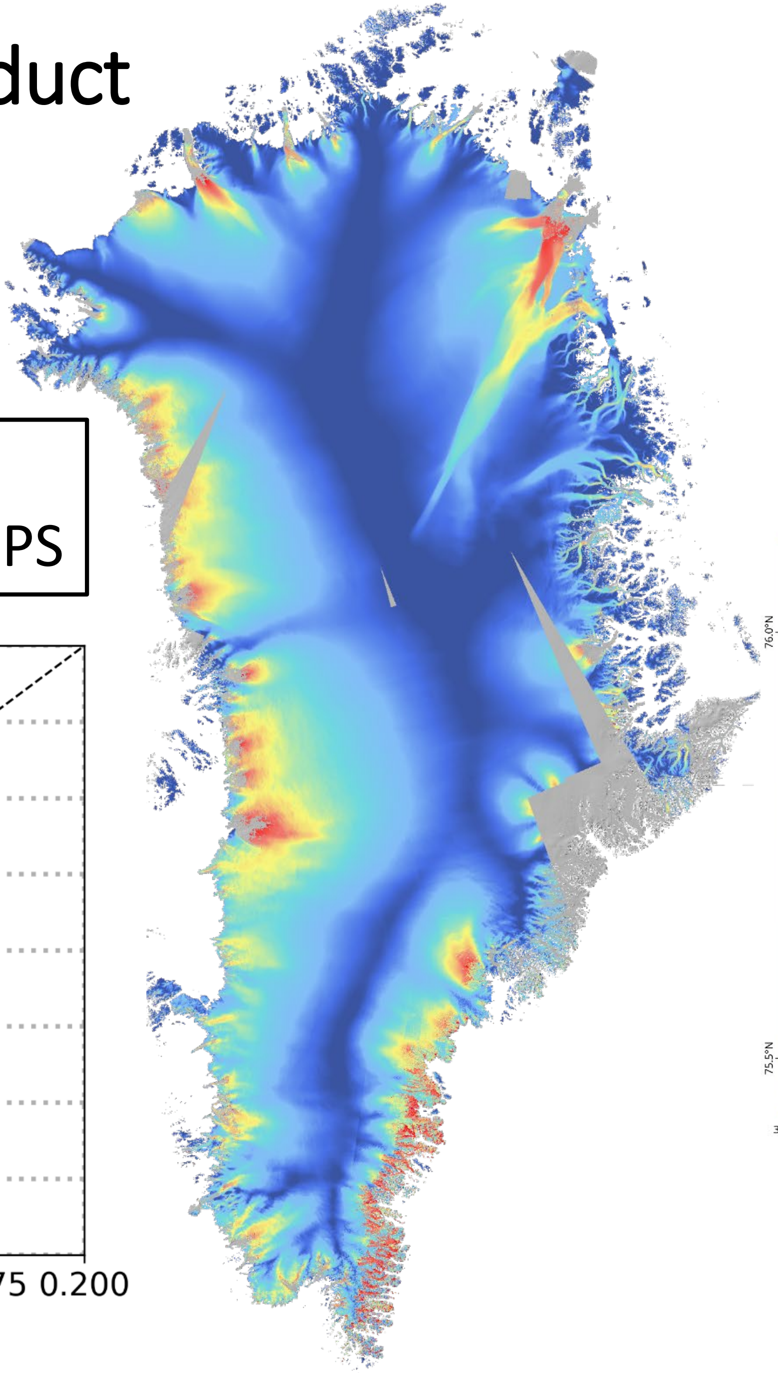
Monthly Products



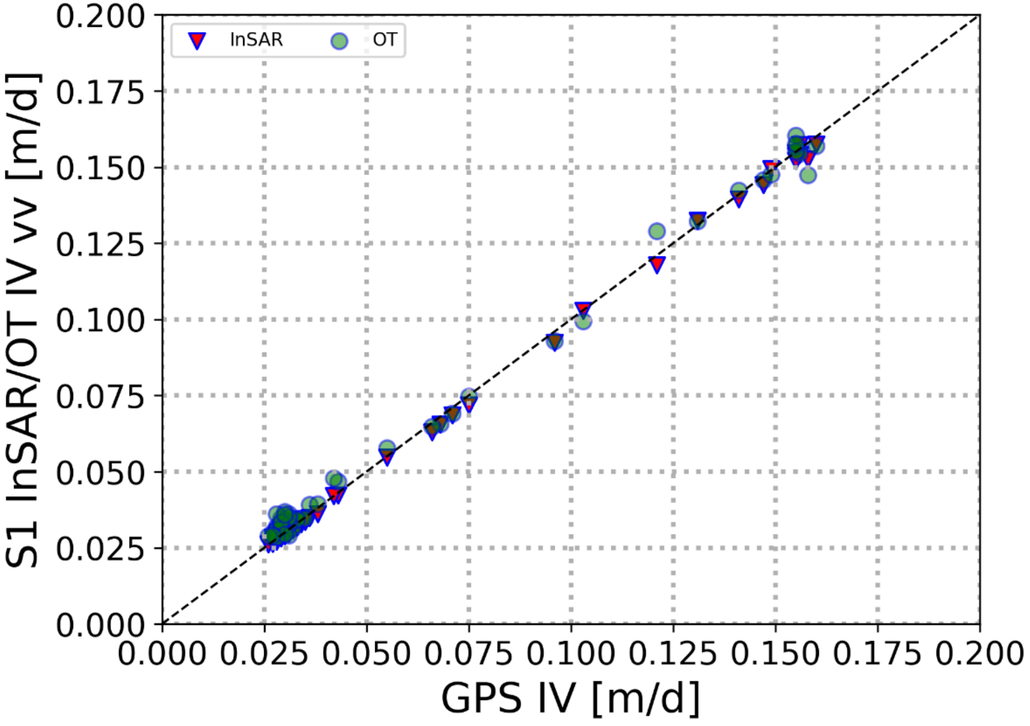
250 m pixels

Method: coherent and incoherent offset-tracking (OT)

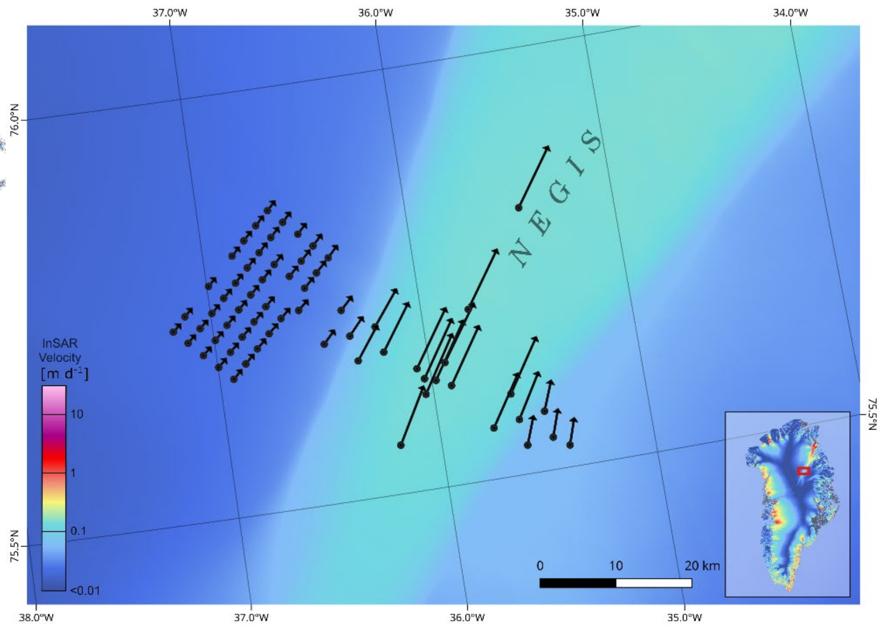
Improved ice velocity product combining INSAR and OT
50 m pixels



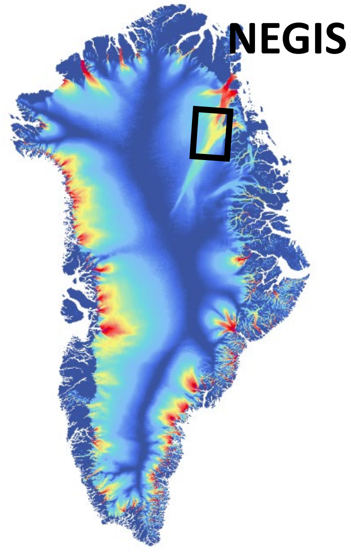
INSAR versus OT
Validation against Eastgrip GPS

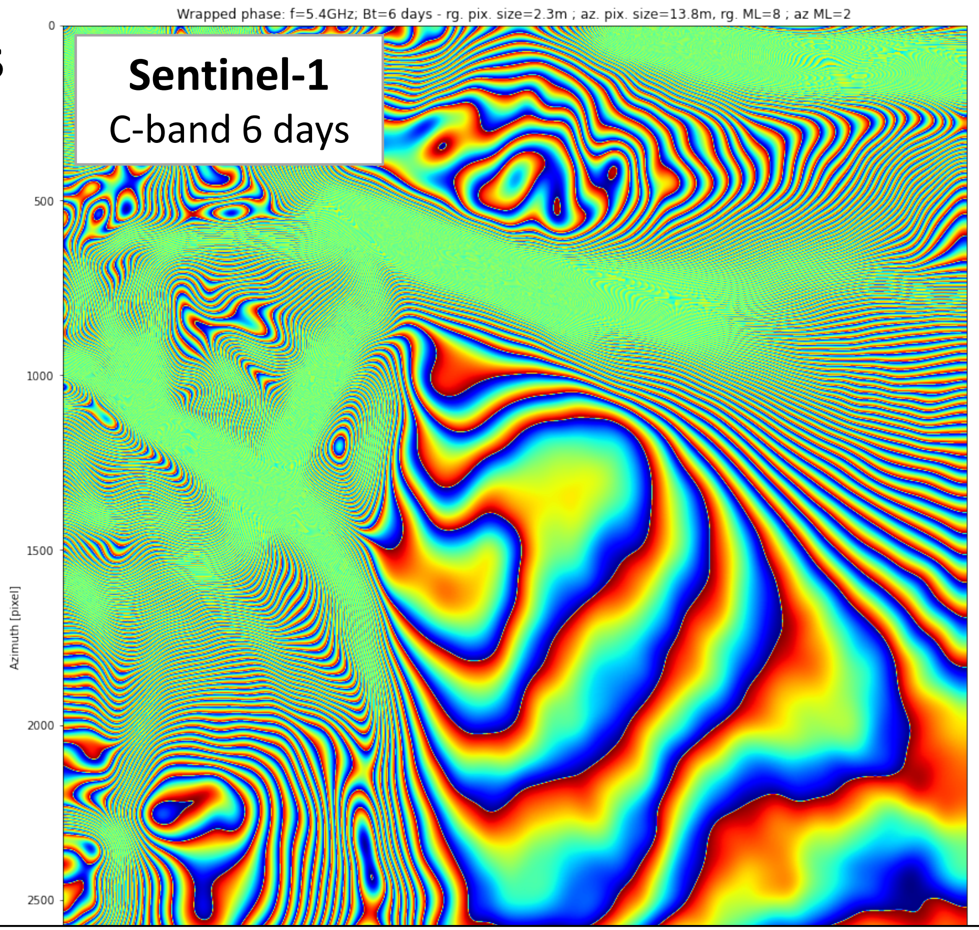


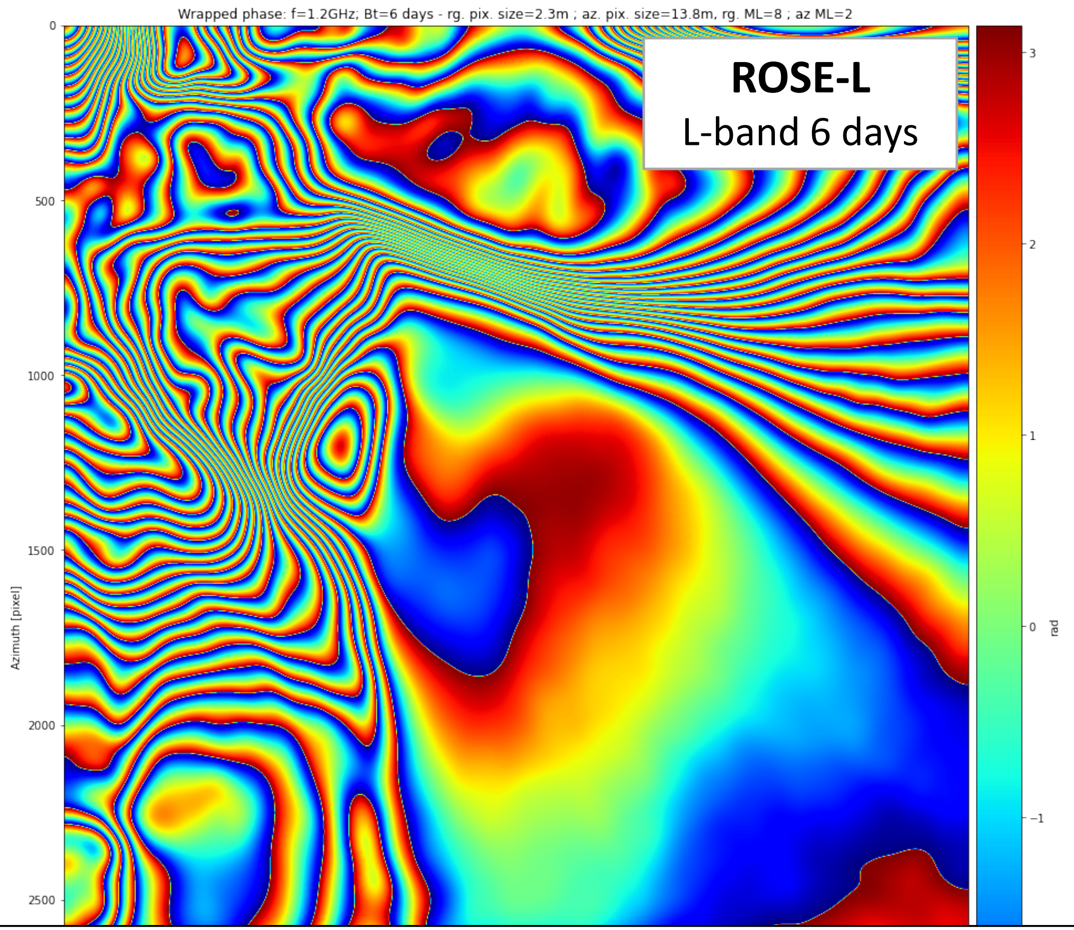
INSAR
Crossing Asc/Desc



S1 versus ROSE-L – simulations of 6-day interferograms







<u>ROSE-L InSAR operating in S1 orbit with 6-day repeat-pass</u>

- Reduced fringe frequency in shear zones and fast moving areas, hence easing phase unwrapping and allowing to extend InSAR IV retrieval further downstream, where C-Band decorrelates.
- L-Band is less sensitive to temporal decorrelation due to snow drift, accumulation → improved quality of interferograms
- Opportunity for combining S1 and ROSE-L INSAR in slow moving areas

Conclusions

- A prototype for retrieving ice velocity from Sentinel-1 TOPS InSAR has been developed, however some issues for automatization need to be solved. The product provides higher spatial resolution (50 m) and is less affected by ionospheric noise.
- The combination of InSAR and Offset Tracking methods is very promising to generate an comprehensive ice velocity product. However, further developments and improvements are needed.
- Sentinel-1 acquisition strategy over Greenland and Antarctica allows systematic monitoring of ice velocity and discharge with high spatial and temporal resolution (6-days, monthly, annual). For fully exploiting the InSAR technique, the coverage of crossing orbits should be further extended.
- The combination of S1 with upcoming L-Band SAR sensors (e.g. ROSE-L, NISAR) will offer interesting constellations for monitoring ice dynamics of polar ice sheets and caps. Studies for synergistic use of C- and L-Band should be initiated.