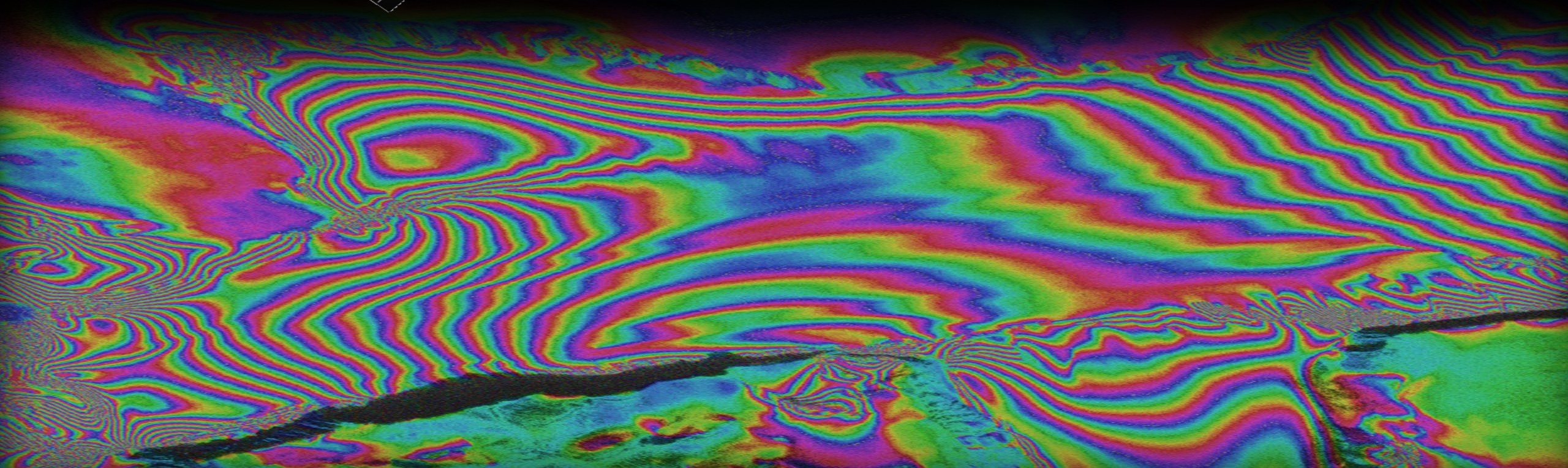
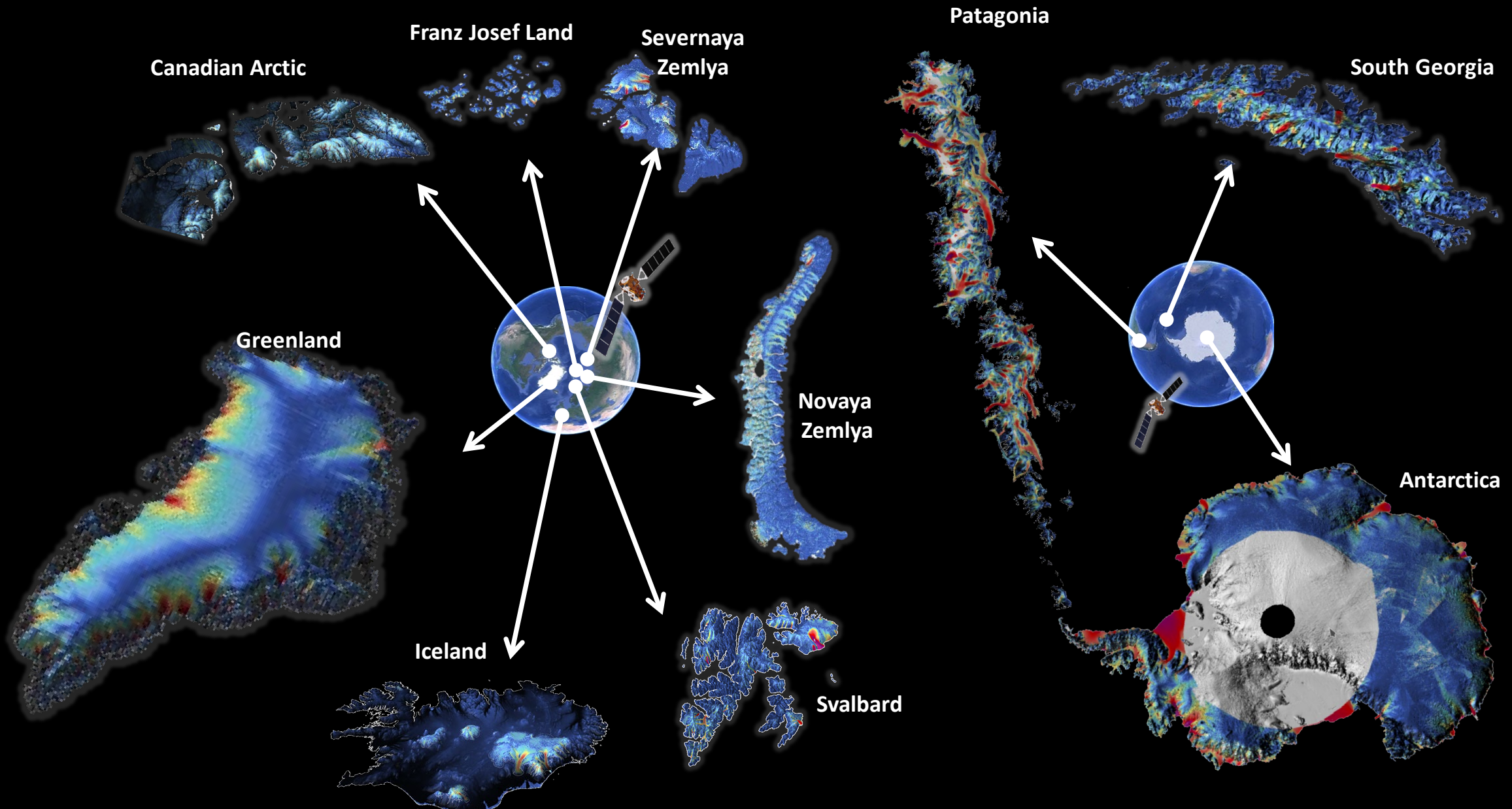


Ice Velocity and Discharge from Ice Sheets using Complementarity of C- and L-Band SAR

Thomas Nagler, Jan Wuite, Helmut Rott, and Markus Hetzenecker
ENVEO • Innsbruck • Austria

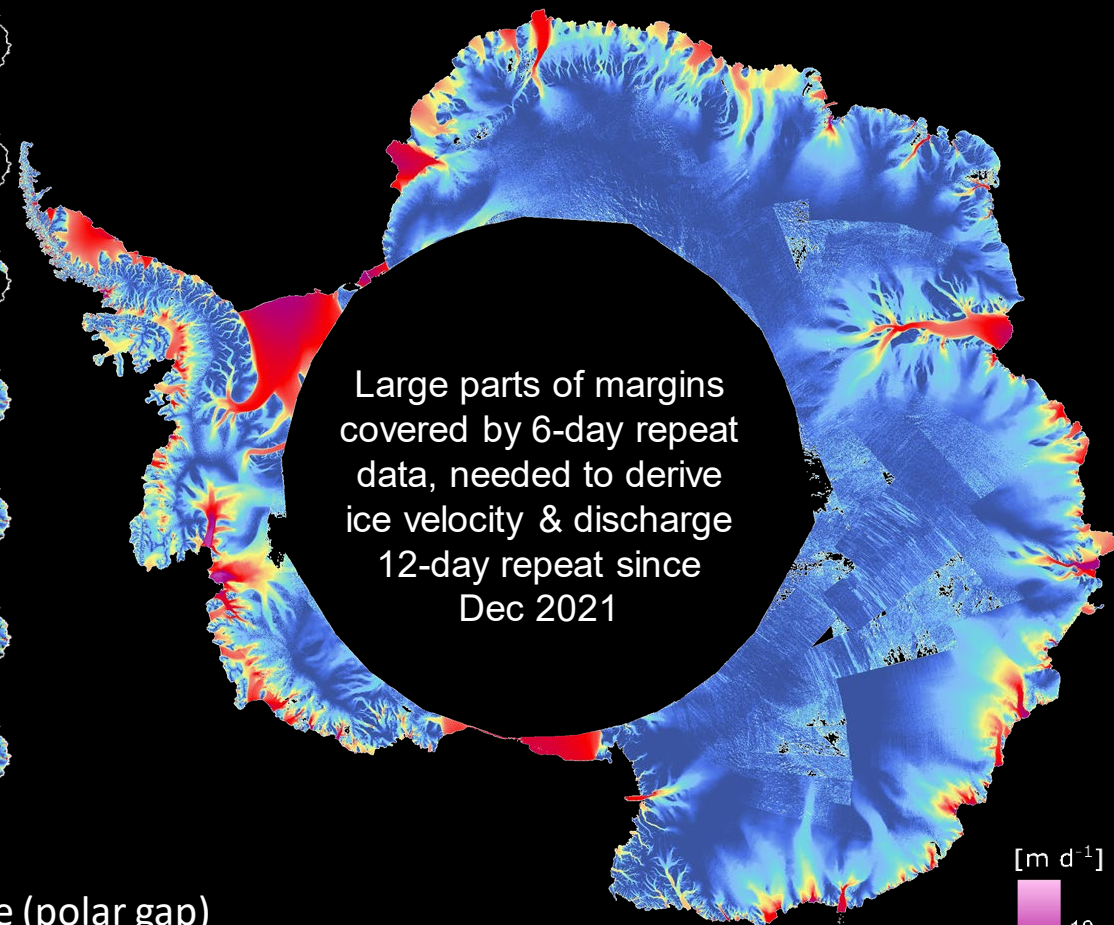
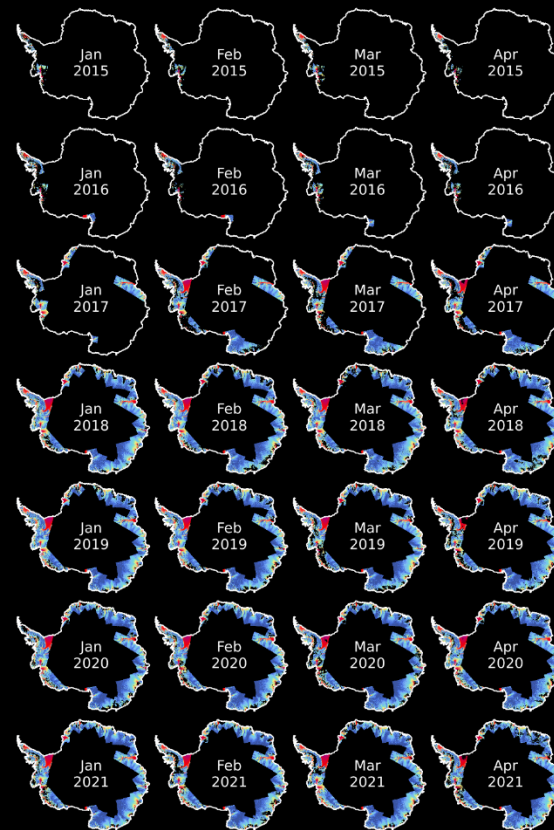
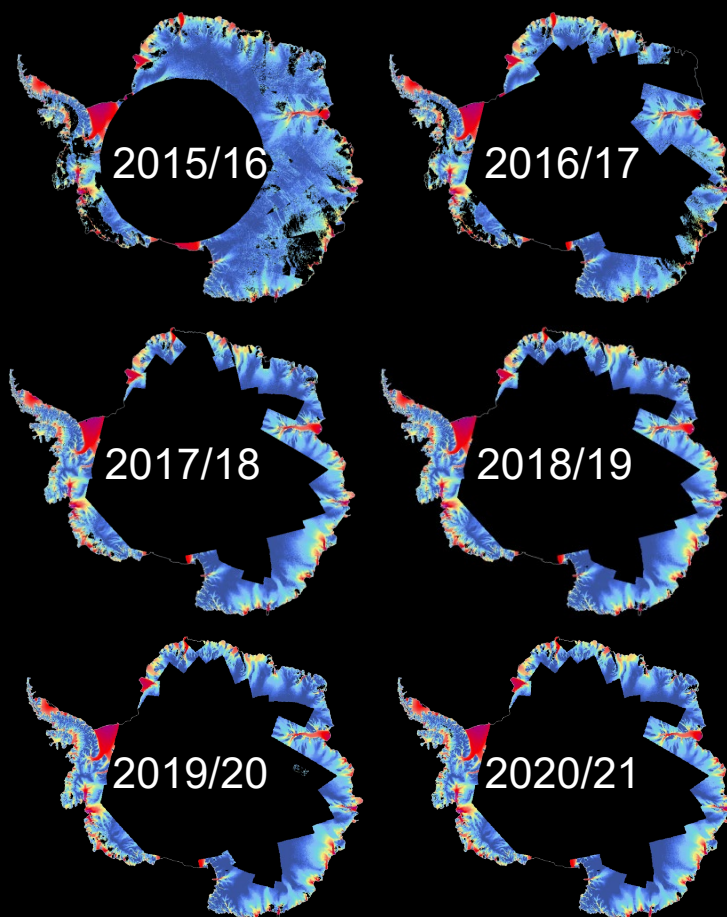


Polar Ice Velocity Mapping using Sentinel-1



All acquired S1 IMS data over these areas are processed after Precise Orbit Data are available

Antarctica: Annual/Monthly Ice Velocity



Key product characteristics

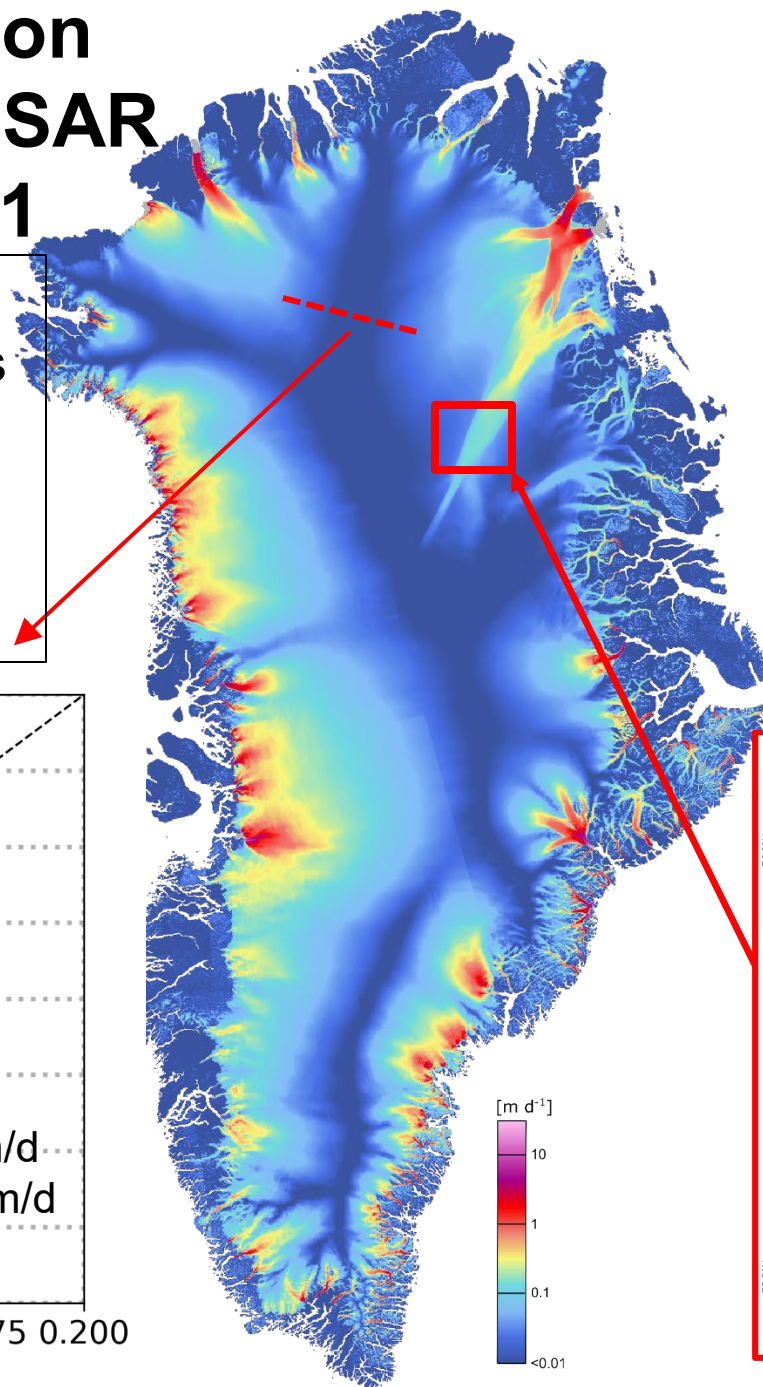
- 1 campaign with full coverage (polar gap) continuous monitoring of margins,
- Timeseries starts in 2015 - Annual updates
- Method: Coherent and Incoherent Offset Tracking (OT)
- E,N velocity components, Dz_{DEM} + uncertainty estimates
- 200m products available: CEDA, AIS CCI, [CryoPortal](#)
- Tide corrected using CATS2008 Tide Model & ERA5 Atmospheric Pressure

Advanced High Resolution IV product combining INSAR and OT (50 m) 2020-2021

Requirements:

Systematic coverage with Asc & Des Passes.

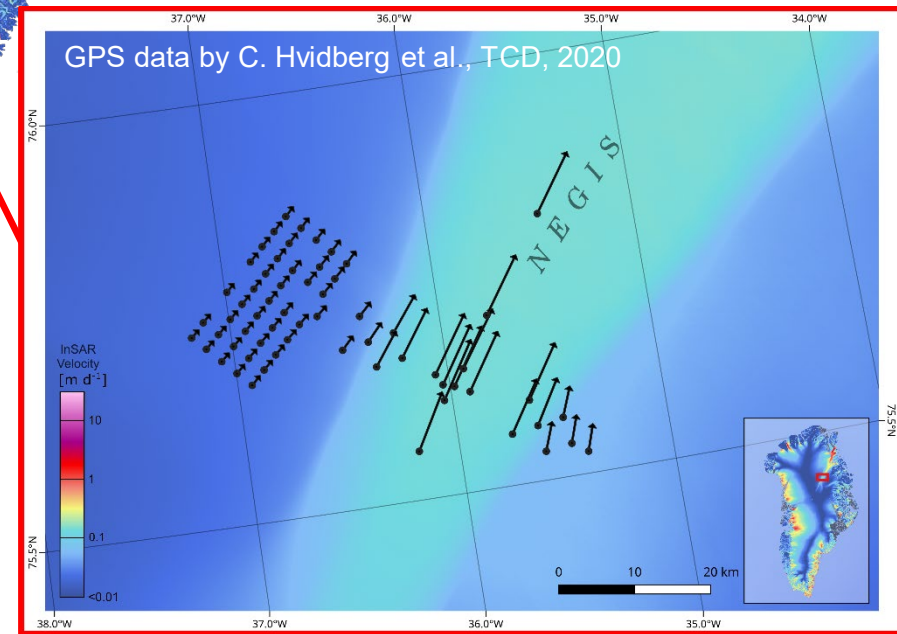
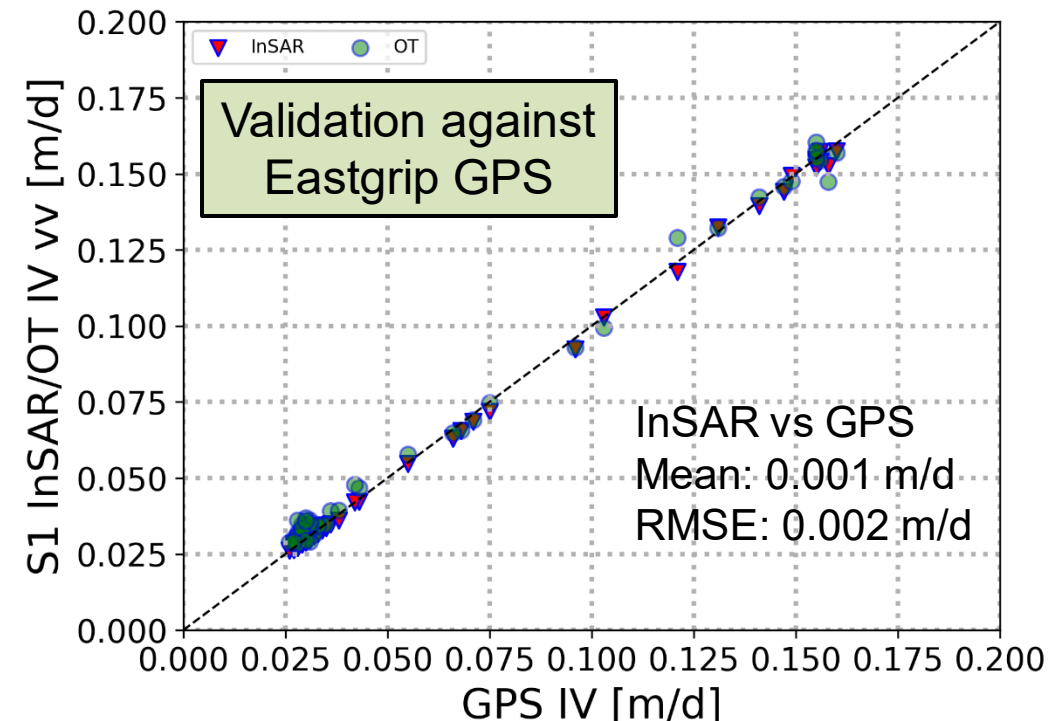
Since Dec 21: only 12 days repeat pass data available, reduced coherence of InSAR signal



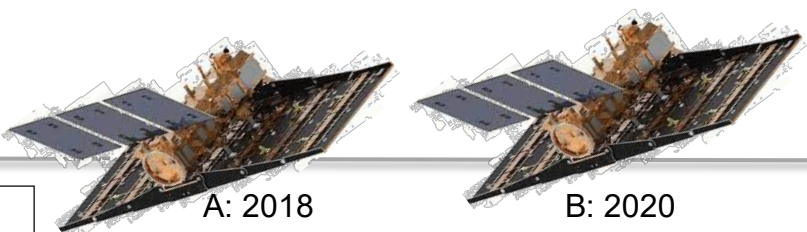
INSAR
Crossing Asc/Desc

INSAR
+ Flow direction from OT

INSAR crossing Asc/Desc
+ **INSAR with OT flow dir.**
+ **Offset-tracking**



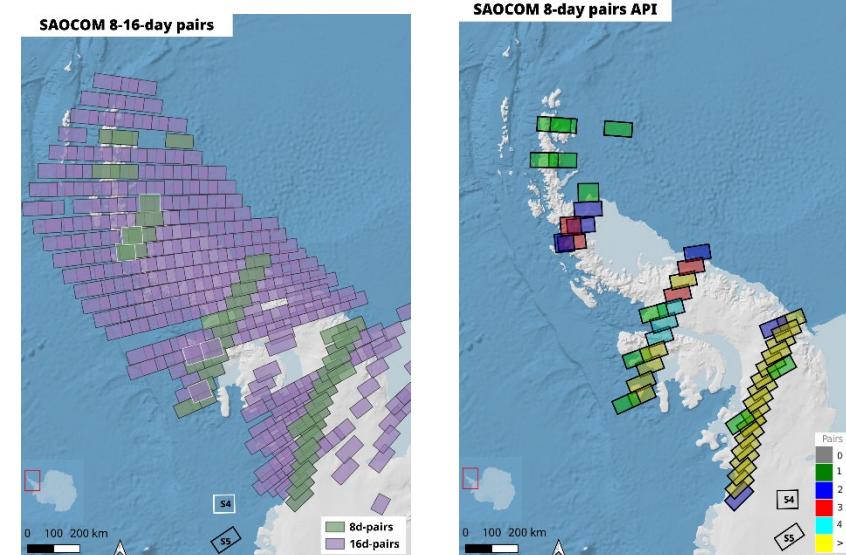
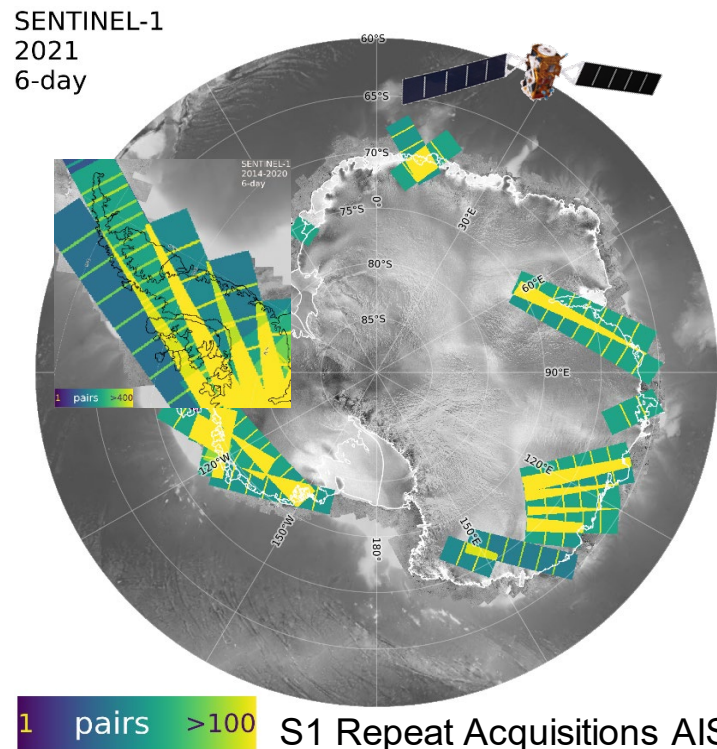
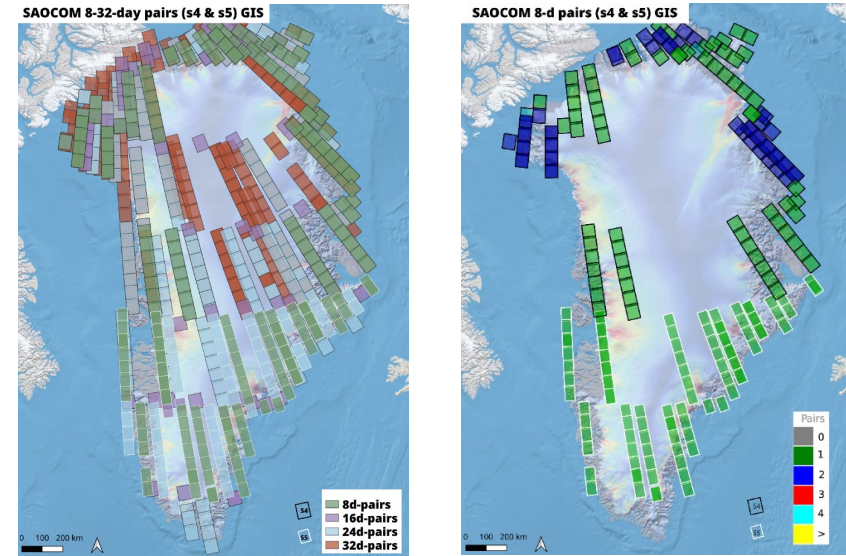
SAOCOM L-BAND SAR



Type	Synthetic Aperture Radar (SAR)
Center Frequency	1275 MHz (L-band)
Maximum Bandwidth	<45 MHz
Transmit Peak Power	3.1 kW
Operational Modes	Stripmap TopSAR
Swath Width	14 - 66 km (beam dependent) for stripmap 108 - 235 km (beam dependent) for topsar
Polarization Modes	Single, dual or quad polarization
NESZ (Noise Equivalent Sigma Zero)	<-25 dB
Antenna Looking Angle	left or right side of path (right side is default)
Incidence Angles	20-50°
Data Quantization	8 bit
Duty Cycle	15% (about 15 minutes per orbit)

8 & 16-day repeat-pass SAR data over ice sheets is provided by the SAOCOM A & B as background mission since 2021

SAOCOM SM Repeat Acquisitions GIS & API

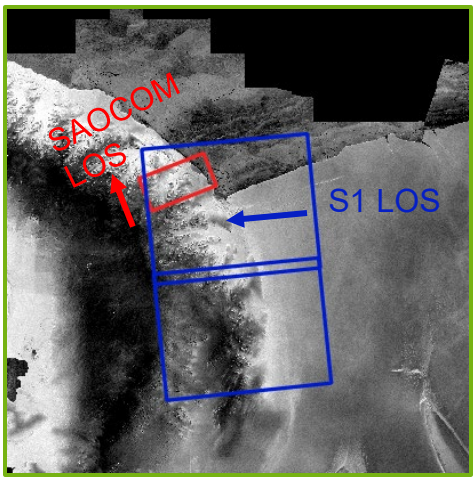
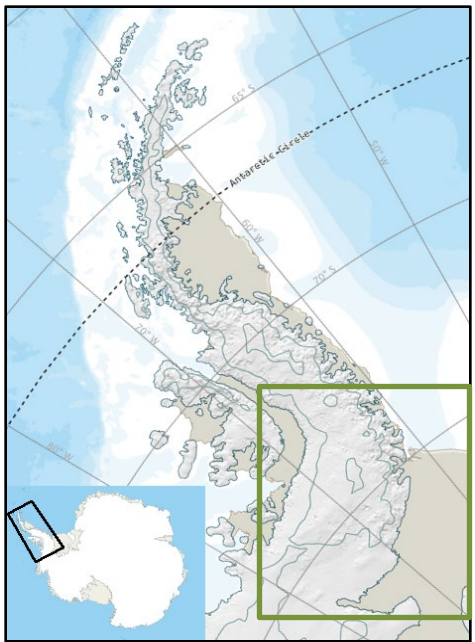


Acquisition Mode	Polarization Mode	Swath Width	Spatial Resolution	Incidence Angle Range (min)
Stripmap	Single, dual or quad	14 km - 66 km	10 m	18° - 49°
TopSAR narrow	Single, dual or quad	150 or 176 km 109 or 110 km	30 m	25° or 38° 18° or 27°
TopSAR wide	Single, dual or quad	354 km 218 km	50 m 100 m	25° 18°

SAOCOM data provided by CONAE

S1 Repeat Acquisitions AIS

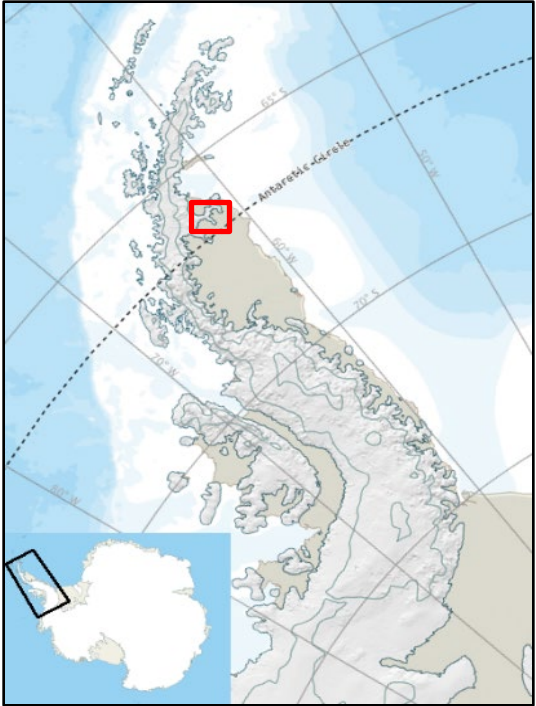
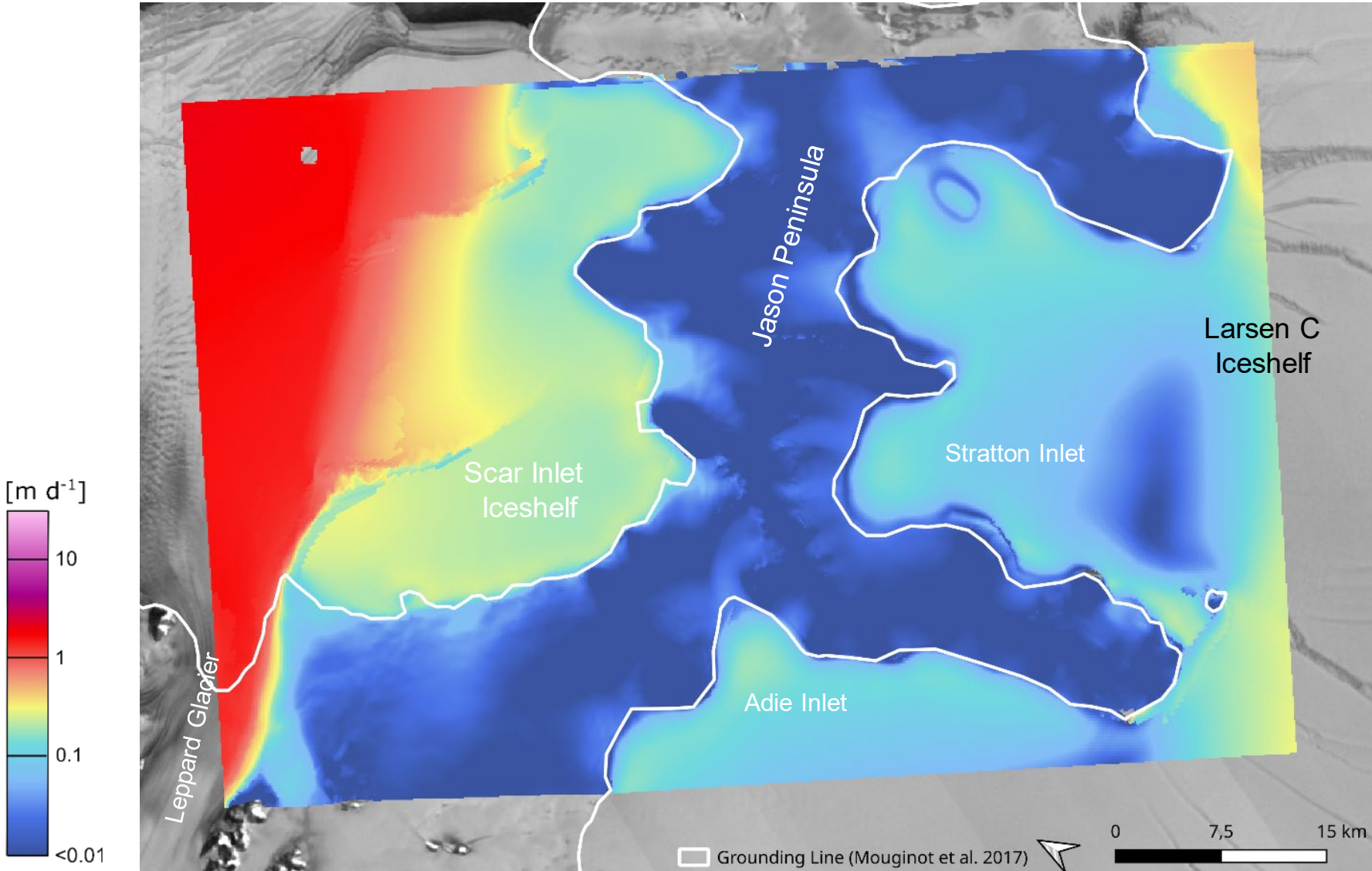
Interferogram Sentinel-1 6 days vs. SAOCOM 8, 16,24 days



Ice Velocity from SAOCOM and Sentinel-1 OT & InSAR



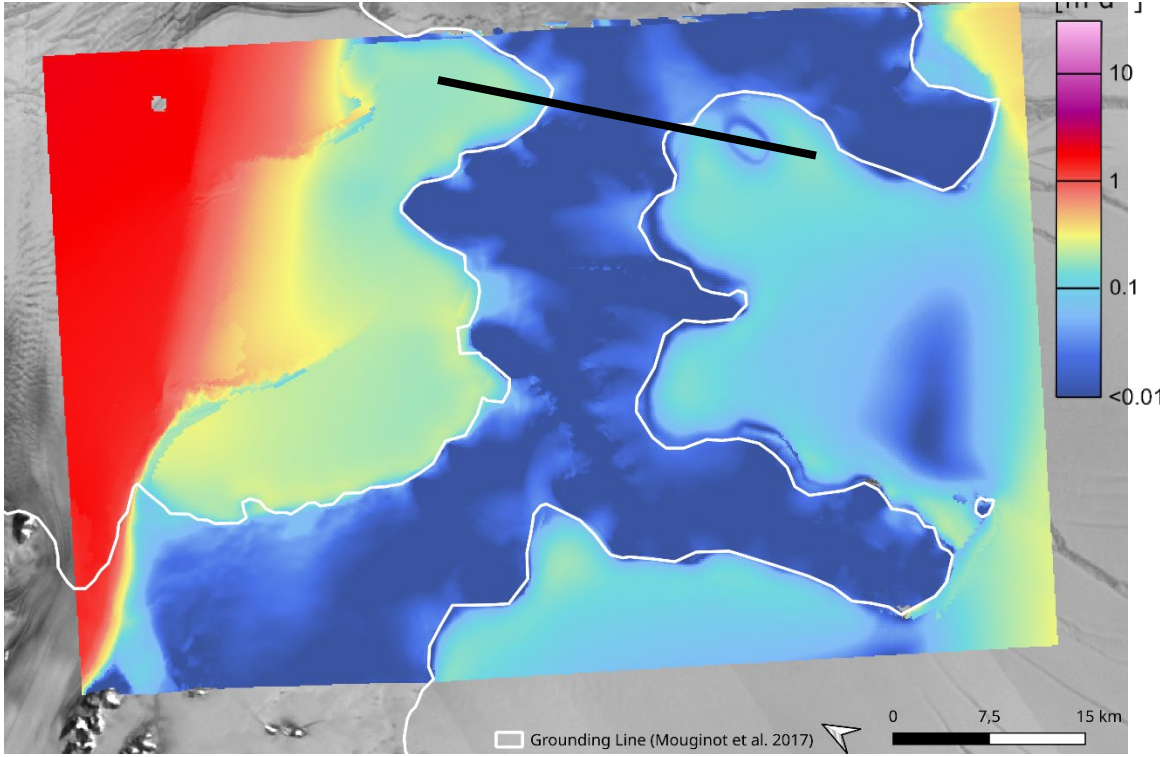
S1/SAOCOM InSAR (Xorbits-tidecor) + SAOCOM INSAR with Flowdir.



InSAR IV combining SAO and S1 & SAO and OT Flow



S1 / SAO InSAR X-orbits/Tide Corr. + SAO InSAR Flowdirection

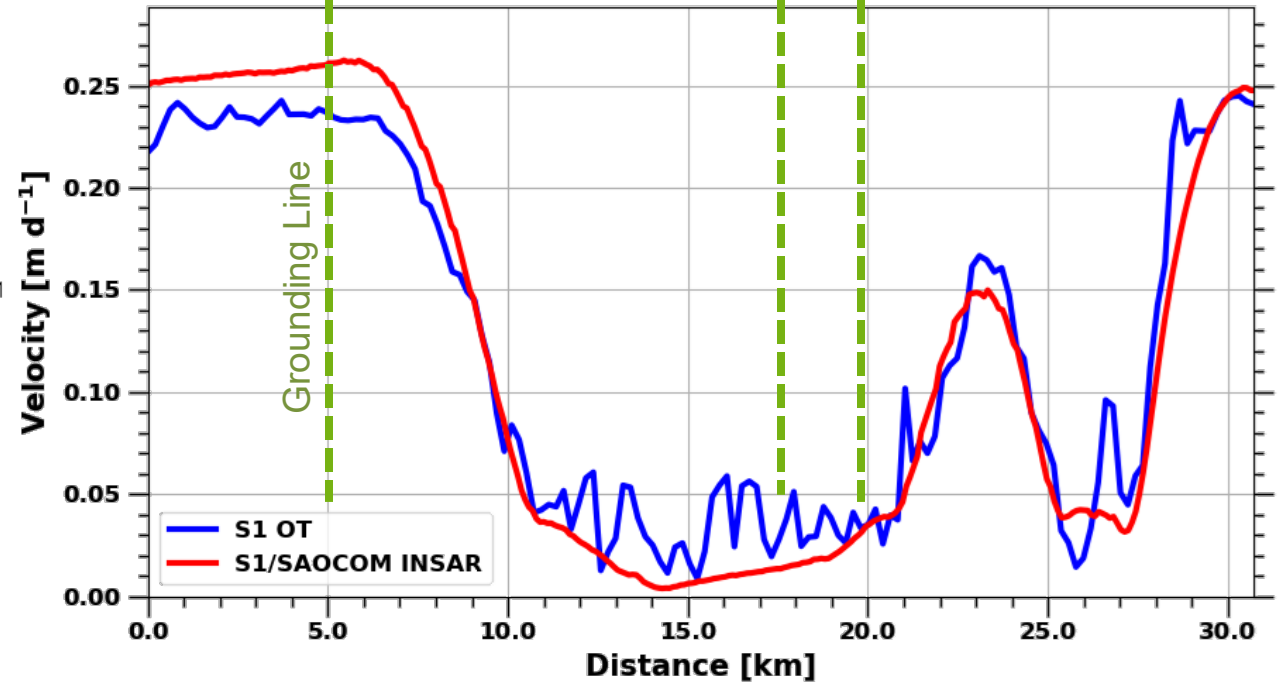


SAOCOM: 2021/08/20 – 2021/09/05
Sentinel-1: 2021/09/07-2021/09/13

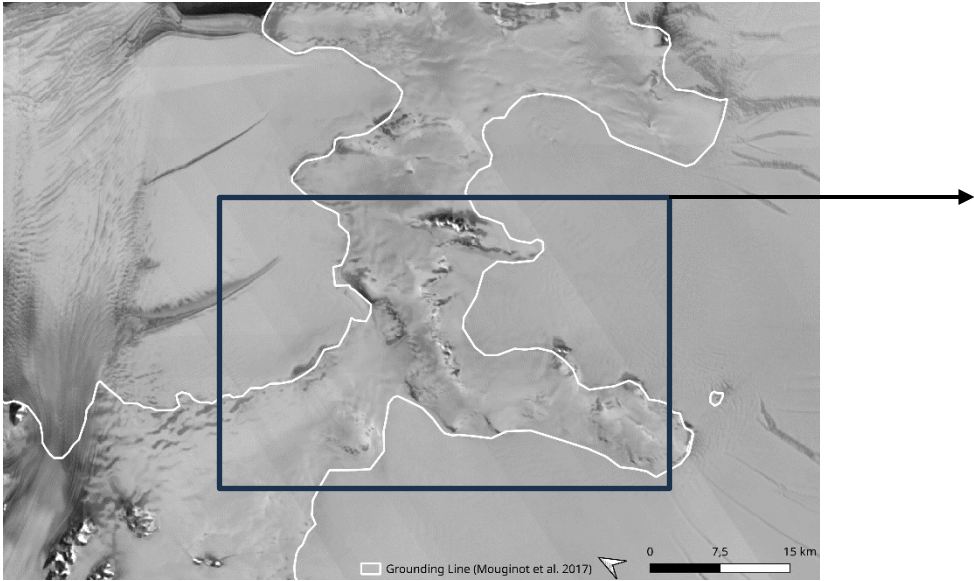
Velocity Profile

S1 Offsettracking (2015-2022)

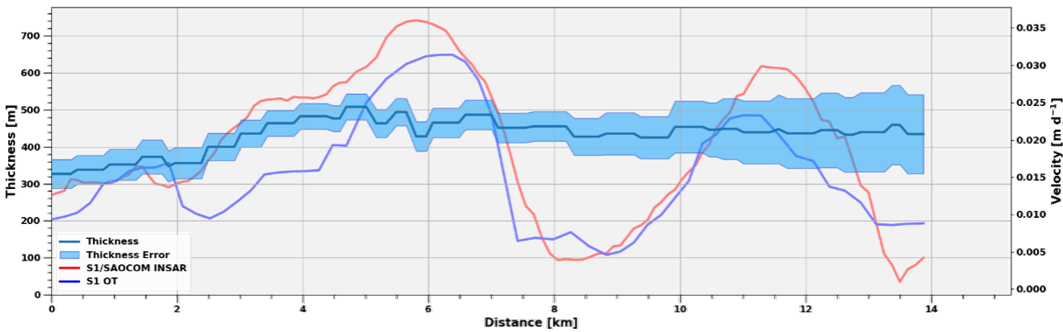
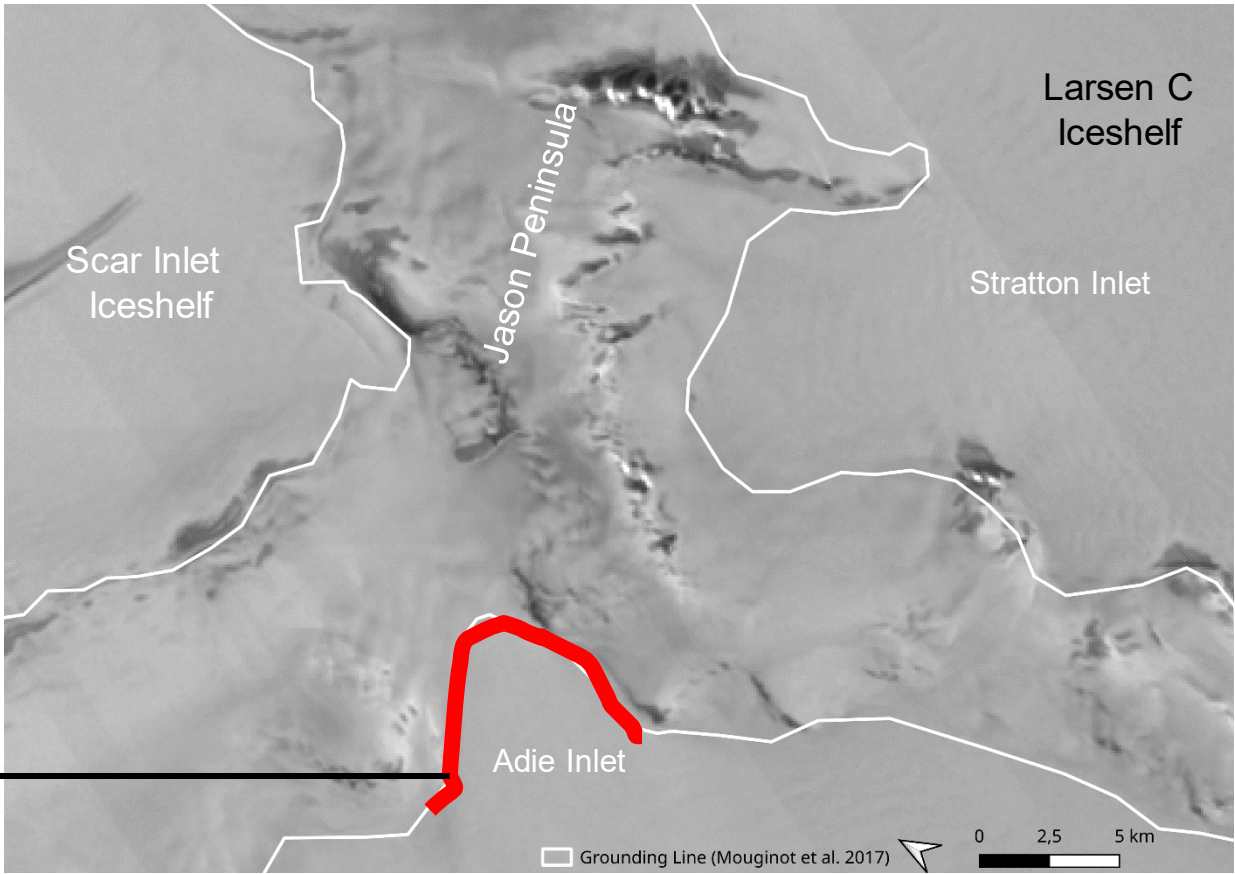
S1 / SAO InSAR X-orbits + SAO InSAR FlowDir.



Discharge from SAOCOM and S1 INSAR based Ice Velocity



Background: TanDEM-X Amplitude (courtesy: B. Wessel)

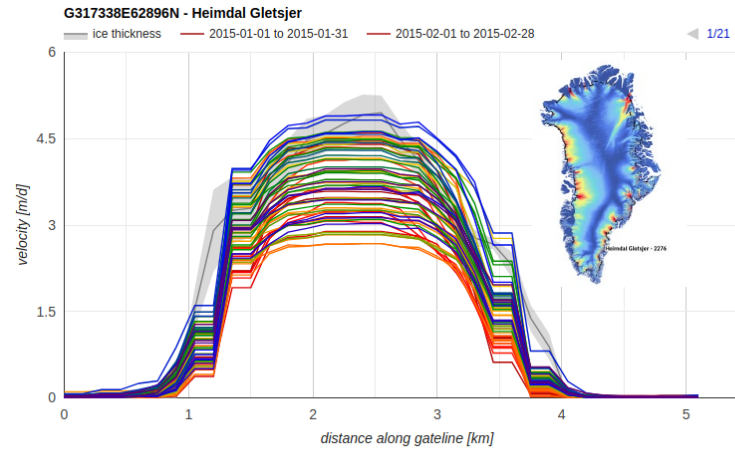
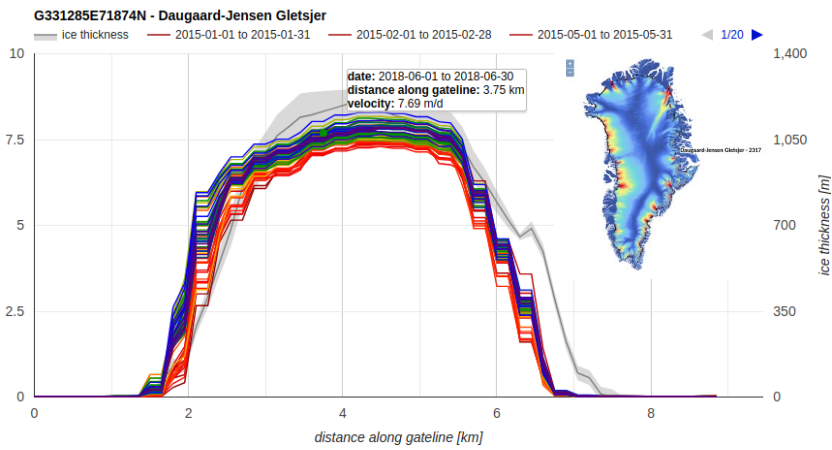


Discharge	
S1 OT:	0.025 ± 0.003 Gt/y
S1/SAOCOM INSAR:	0.037 ± 0.003 Gt/y

Combined S1 - SAOCOM INSAR provides smoother ice flow velocity, revealing smaller tributaries in greater detail and providing more accurate discharge estimates – but reference IV data for absolute validation are needed.

Mass Flux and Ice Discharge

Map view of mass flux change per glacier

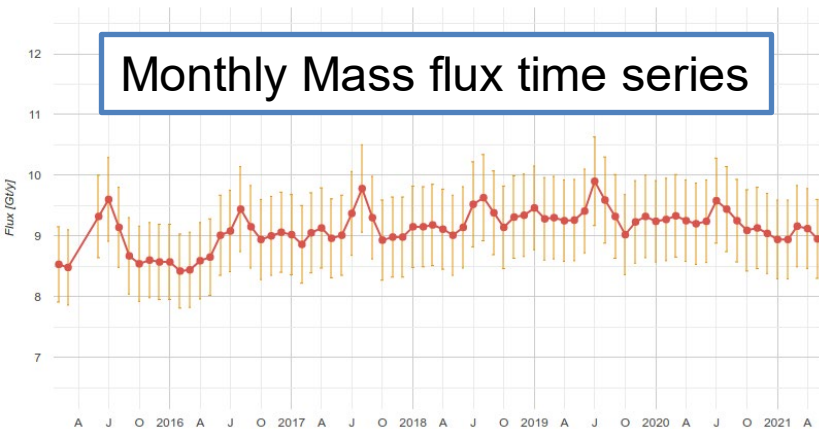


Cross profiles (IV & H), gate specific information

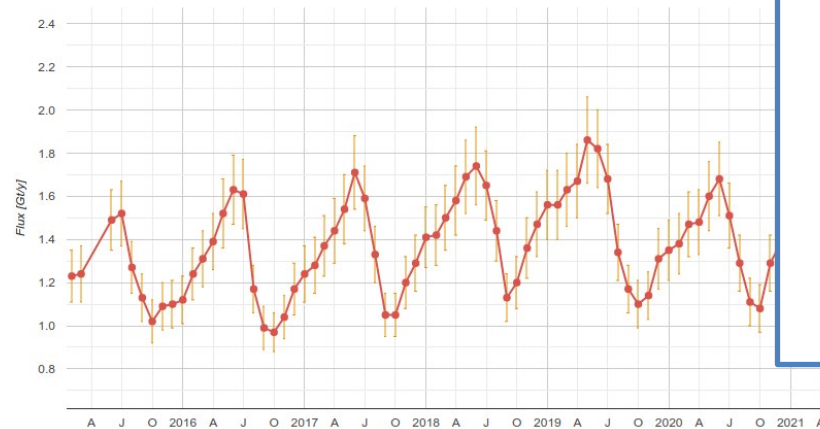
Glacier	Gateline ID	Gateline Source	Basin	Sub-basin	Type	Gate Width [km]	Ice
G309708E68863N Saqqarluup Sermlia	2252	ENVEO	6	6.2	GrIS	33.75	

G331285E71874N - Dagaard-Jensen Gletsjer

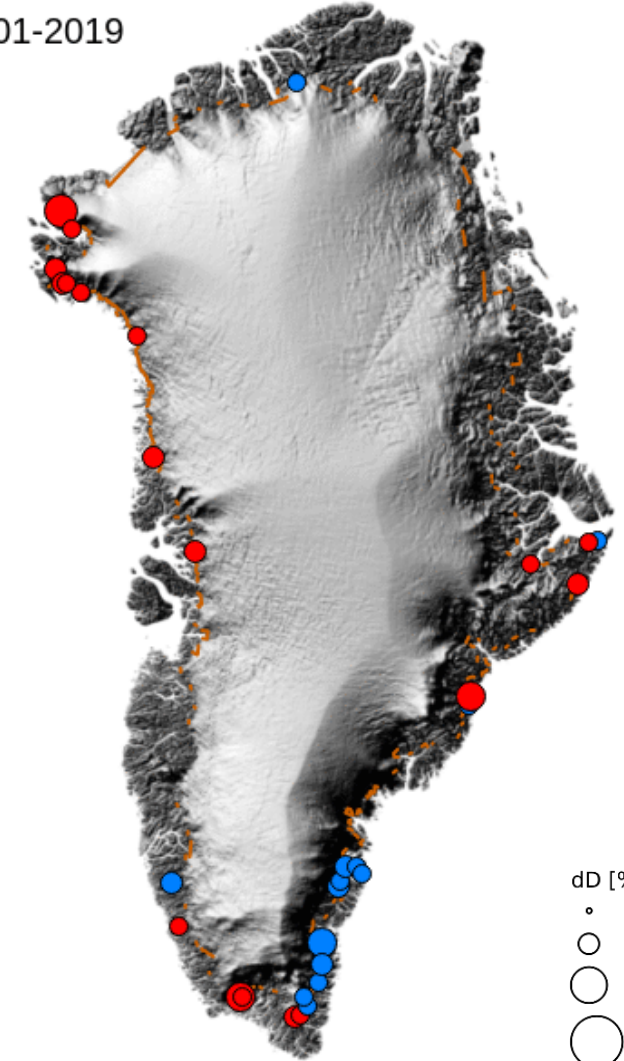
Monthly Mass flux time series



G317338E62896N - Heimdal Gletsjer

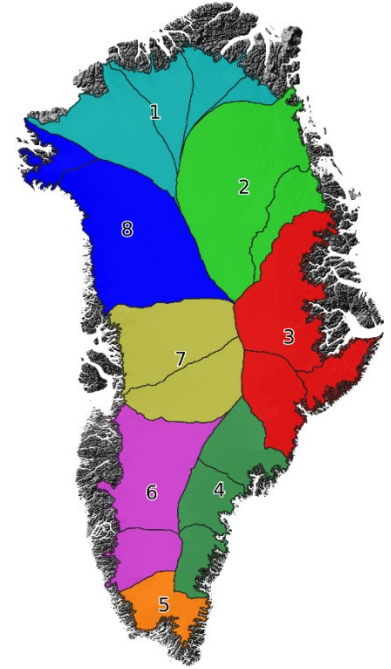
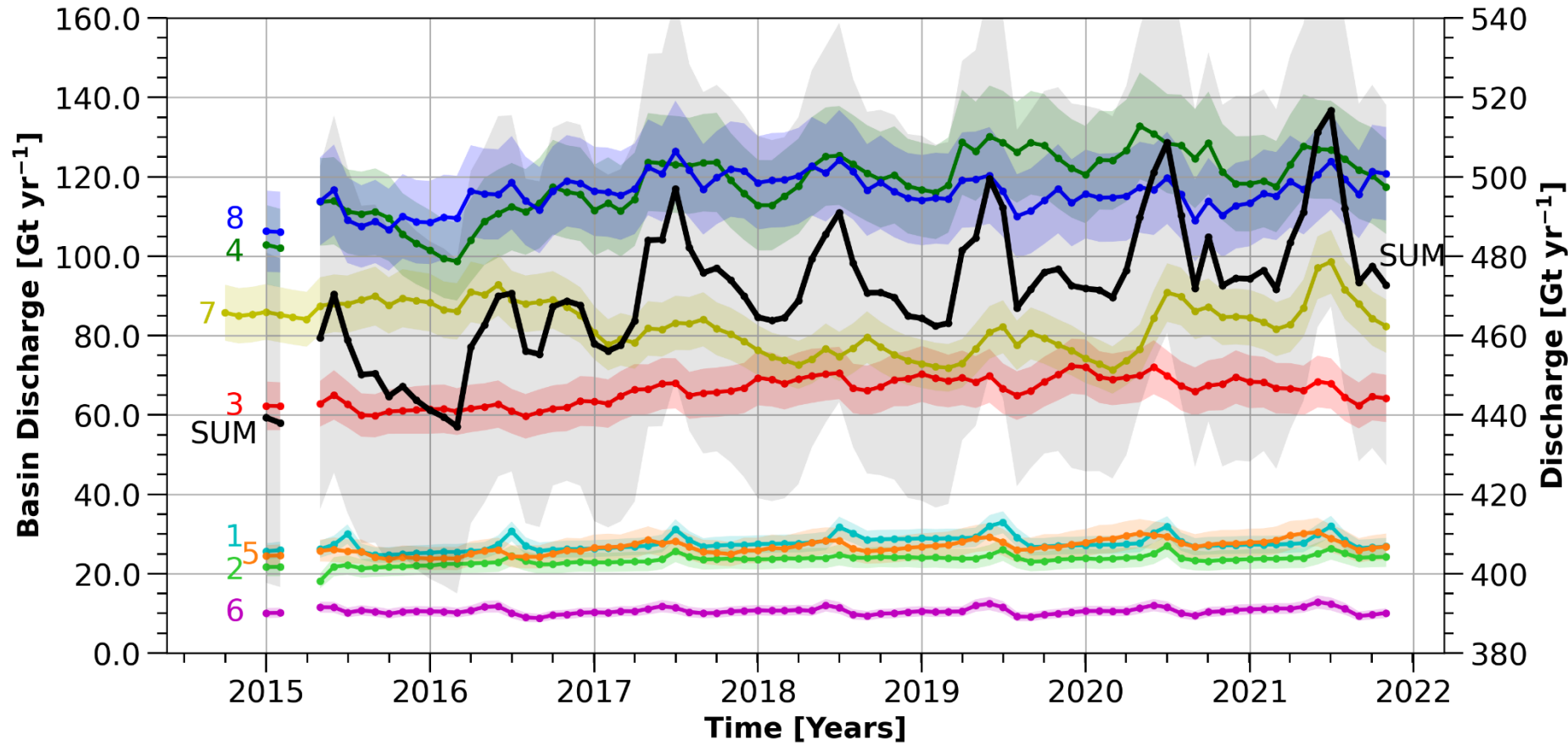


01-2019



2015 A J O 2016 A J O 2017 A J O 2018 A J O 2019 A J O 2020 A J O 2021 A

Ice Discharge – Monthly Basin & Sum Discharge



GIS Annual Discharge [Gt/y]	
2014/15:	445.5 ± 42.7
2015/16:	450.5 ± 43.5
2016/17:	469.0 ± 45.9
2017/18:	471.3 ± 46.4
2018/19:	471.5 ± 46.4
2019/20:	478.3 ± 46.5
2020/21:	481.4 ± 46.6

- The study shows mayor improvements for IV monitoring using synergy of C- & L-band InSAR, demonstrated by combining S1 and SAOCOM data
- L-Band InSAR covers areas decorrelating in C-band, being less affected by decorrelation in areas with strong velocity gradients due to reduced fringe frequency enabling reliable phase unwrapping.
- L-band is more sensitive to disturbances by ionospheric effects, which need to be corrected.
- L-/C-band (SAOCOM/S1) InSAR combination provides smooth ice flow over a wide range of velocity magnitudes, allowing to monitor also small tributaries in great detail and providing more accurate discharge estimates.
- The work contributes to the preparation of processing tools and acquisition planning for the upcoming and the Copernicus ROSE-L Mission, and NISAR L-Band Mission (scheduled for launch in Jan 2024)

SAOCOM data were provided by CONAE

