Glaciers_cci+: Investigating new algorithms to reveal the dynamics of unstable glaciers in the Arctic and HMA

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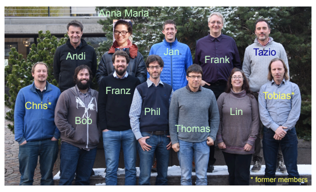
Team and schedule

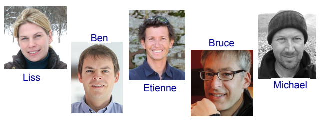
Consortium

Country	Short name	Full name	Role	Uni/Comp.	WP lead
CH	GIUZ	Department of Geography, University of Zurich	Prime contractor	University	500, 600
CH	GAMMA	Gamma Remote Sensing AG	Sub-contractor	Company	300, 400
AU	ENVEO	Environmental Earth Observation	Sub-contractor	Company	400, 300
NO	GUIO	Department of Geosciences, University of Oslo	Sub-contractor	University	200
UK	SEEL	School of Earth and Environment, University of Leeds	Sub-contractor	University	100



Climate Research Group

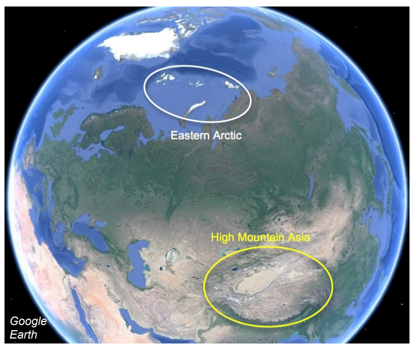
Name	Organisation	Location	Expertise	Role
Liss Andreassen	NVE	Oslo, NO	Glacier mapping and monitoring	GTN-G Advisory Board, IACS representative
Ben Marzeion	UB	Uni. Bremen, DE	Glacier modelling	Climate impacts
Etienne Berthier	LEGOS-CNRS	Uni. Toulouse, FR	Geodetic mass balance	Science advice, validation
Bruce Raup	NSIDC	Boulder, CO, US	GLIMS database	Data Standards, Quality
Michael Zemp	WGMS	Uni Zurich, CH	Glacier monitoring	Data base standards, TOPC



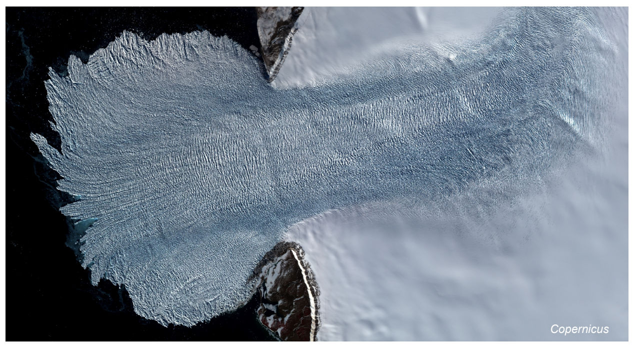
Gantt Chart

Nr.	Task	Deliv.	Name	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Lead
				Year 1 (2019)				Year 2 (2020)				Year 3 (2021)				
1	1	D1.1	URD	N				U				U				SEEL
2		D1.3	PVP		N						U					SEEL
3	2	D2.1	ATBD				U									GUIO
4		D2.2	EUB				N					U				GUIO
5	3	D3.1	SSD						U							Gamma
6		D3.2	CRDP						N		U					Enveo
7	4	D4.1	PVIR										N			Enveo
8		D4.2	PUG										U			Gamma
9	5	D5.1	CAR												N	GIUZ
10		D5.2	PUB							N					N	GIUZ
11	6	D6.1	QSR	X	X	X	X	X	X	X	X	X	X	X	X	GIUZ-PM
12		D6.3	PMP		X		X		X		X		X		X	GIUZ-PM
13		D6.4	PSH				X				X				X	GIUZ-SL
14		D6.2	FR												X	GIUZ-SL
15	Project Meetings				PM1-TC		AR1		PM2-TC		AR2		PM3-TC	User WS	AR3	
16	CCI Meetings			Colocation		CMUG		Colocation		CMUG	MTR	Colocation		CMUG		
17	Milestones			KO	MS1		MS2		MS3		MS4		MS5		MS6	

Study region and project goals



Location of the two study regions

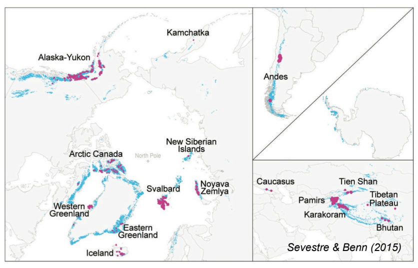


Surging outlet glacier of the Vavilov Ice Cap (Sentinel-2 12.9.2017)

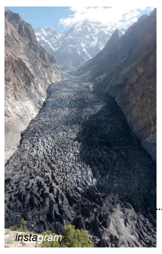
- Focus on two regions with several instable / surge-type glaciers (Arctic / HMA)
- Following changes in extent, elevation and velocity at high temporal resolution
- Use full suite of satellite sensors providing such data (optical, microwave, DEM)
- Create longest possible time series (full archive) to reveal the historic development
- Analyse the densest possible time series to follow fast events (S1/2 & combi w/ L8)
- Use the best algorithms to derive quantitative data with high quality

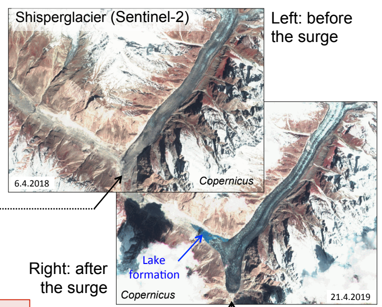
What are dynamically unstable glaciers?

Global occurrence of surge-type glaciers



Surging Shisperglacier in the Karakoram


Uphill view of the surge



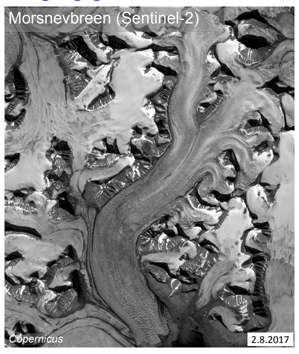
Left: before the surge

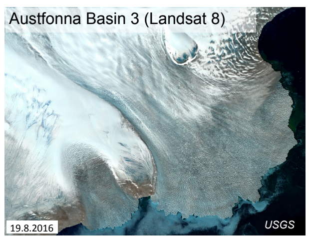
Right: after the surge


The front of the surging Shisperglacier

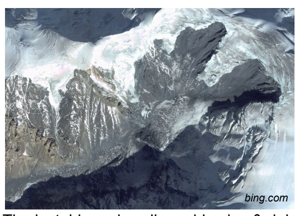
- A dynamically unstable or surging glacier suddenly bursts into a high speed mode (factor 10-100), resulting in a highly crevassed surface and massive downward mass transport
- Such glaciers are found in selected regions around the world
- They can create natural hazards (outburst of damned lakes), collapse (examples from Tibet), and contribute to sea level
- Their behaviour is still not well understood and requires the full range of remote sensing data being applied

Surging glaciers in Svalbard





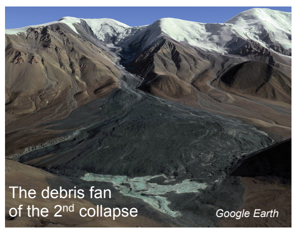
Collapsing glaciers in Tibet

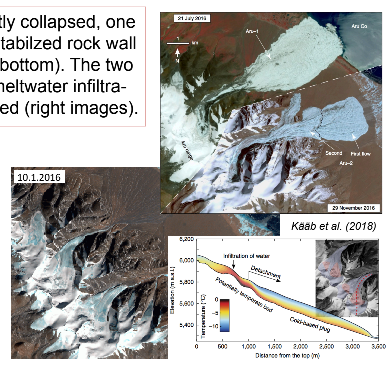


The instable rock wall provides ice & debris


The empty glacier bed of Aru 1

In Tibet, several glaciers have recently collapsed, one of them already 4 times due to a destabilized rock wall providing new material (left, top and bottom). The two Aru glaciers likely collapsed due to meltwater infiltration & a tongue partly frozen to the bed (right images).



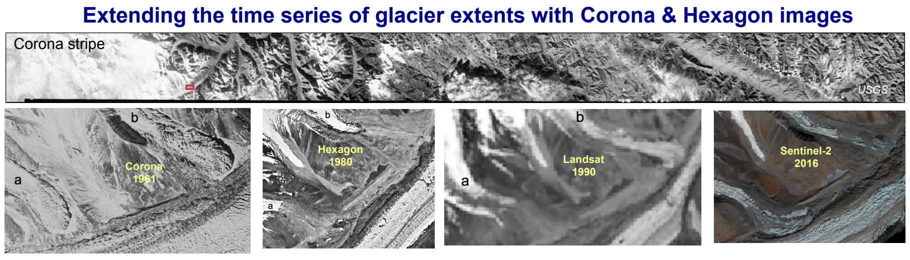


Algorithm development

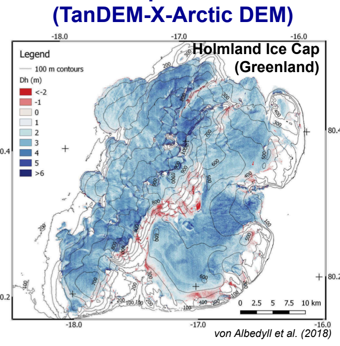
Possibilities of further algorithm development

	Glacier extent	Elevation change	Velocity
Algorithm development	(a) Excluding ocean water & sea ice with band ratio	(c) Estimation of radar penetration into snow/firn/ice	(g) Interferometric techniques for IV & drainage divides
Activity	Threshold finding, filtering	Comparison with ArcticDEM	Comparison with optical
Satellites	Optical (Landsat, Sentinel 2, ASTER)	Cryosat-2 / TanDEM-X vs. ICESat-2 / ArcticDEM	SAR (Sentinel 1, ERS1/2, JERS, PALSAR, Radarsat)
Aux. datasets	ArcticDEM, TanDEM-X	Field data Svalbard	ArcticDEM, TanDEM-X
Validation	intercomparison	2 m Arctic DEM	DGPS (Svalbard)
ADC and [TR]	(3) [TR-18a]	(1), (3) and (7)	(6), [TR-16]
Algorithm development	-	(f) Accumulation / ablation rates, seasonal trends	(h) Dense time series (mass flux & surge characteristics)
Activity	-	Measure dh/dt	Combining different sensors
Satellites	-	Cryosat-2, Sentinel-3	SAR & optical sensors
Aux. datasets	-	Reference DEM, outlines	DEM & bed topography
Validation	-	Pleiades, field data, ICESat	
ADC and [TR]	-	(6), [TR-15]	(6), (7) and (9), [TR-16]
Algorithm development	(a) Automated mapping of debris-covered glaciers	(d) Removal of sensor biases (voids / artefact interpolation)	(h) Dense time series, match Landsat/Sentinel w/ SAR
Activity	Test of new methods	Thresholds if surging?	Co-registration?
Satellites	Optical, thermal & SAR (coherence images)	Various DEMs: SRTM, ALOS AW3D30, TanDEM-X, HMA	Landsat 8 / Sentinel-2, various SAR
Aux. datasets		Glacier outlines	Accurate DEMs
Validation	SPOT, Plejades	Spatially complete DEM	Independent datasets
ADC and [TR]	(1) and (6), [TR-14]	(1) and (7)	(6), (7) and (9), [TR-16]
Algorithm development	(b) Historic glacier extents and DEMs)	(e) Seasonal elevation changes	-
Activity	Orthorectification / mapping		-
Satellites	Corona / Hexagon	ICESat-2, TDX/TSX	-
Aux. datasets	External DEM	Useful reference DEM	-
Validation	Glacier outlines	Consistency with flow	-
ADC and [TR]	(4) and (7)	(6), [TR-15]	-

Extending the time series of glacier extents with Corona & Hexagon images

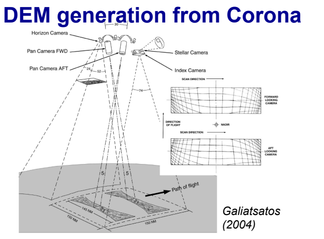


Radar penetration (TanDEM-X-Arctic DEM)

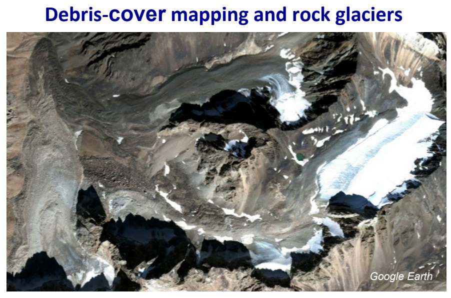


Hillshade of a DEM created from Corona stereo scenes

DEM generation from Corona



Debris-cover mapping and rock glaciers

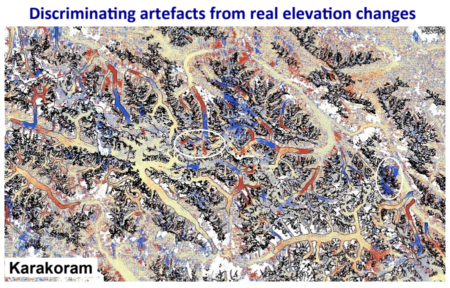


Discriminating debris-covered glaciers from rock glaciers is often challenging, even at very high spatial resolution.

To investigate these glaciers at the required level of detail, we have to further improve algorithms and develop new ones, e.g.:

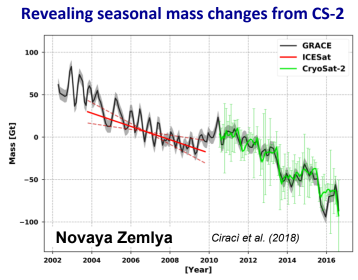
- use keyhole mission data to extend the time series (CDR), create DEMs from stereo images, and analyse surge cycles
- find methods to detect DEM artefacts, correct radar penetration and create dense elevation time series (seasonal mass balance)
- determine the spatio-temporal variability of flow velocities from dense time series of satellite scenes, incl. merging S1, L8 & S2

Discriminating artefacts from real elevation changes



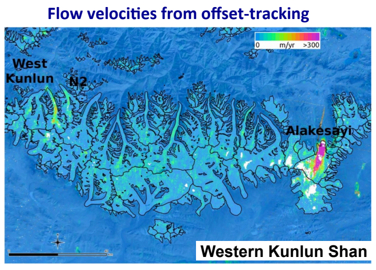
Elevation differences from SRTM - TanDEM-X DEM

Revealing seasonal mass changes from CS-2

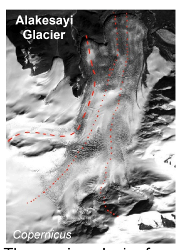


Mass change time series from 3 different sensors

Flow velocities from offset-tracking

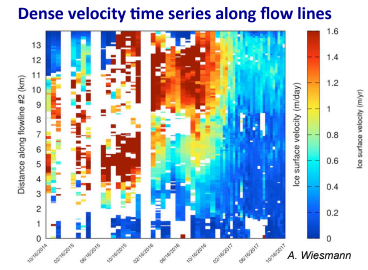


Flow velocities derived from Sentinel-1



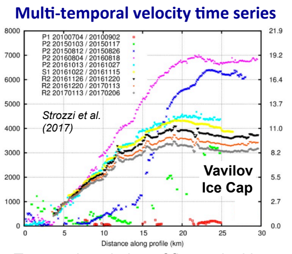
The surging glacier from S2 with flow lines (red)

Dense velocity time series along flow lines



Time-distance plot of flow velocities from Sentinel-1

Multi-temporal velocity time series



Temporal evolution of flow velocities during the surge of Vavilov Ice Cap

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