Exploring the Potential of ICEYE Imagery for Operational Landslide Mapping & Monitoring

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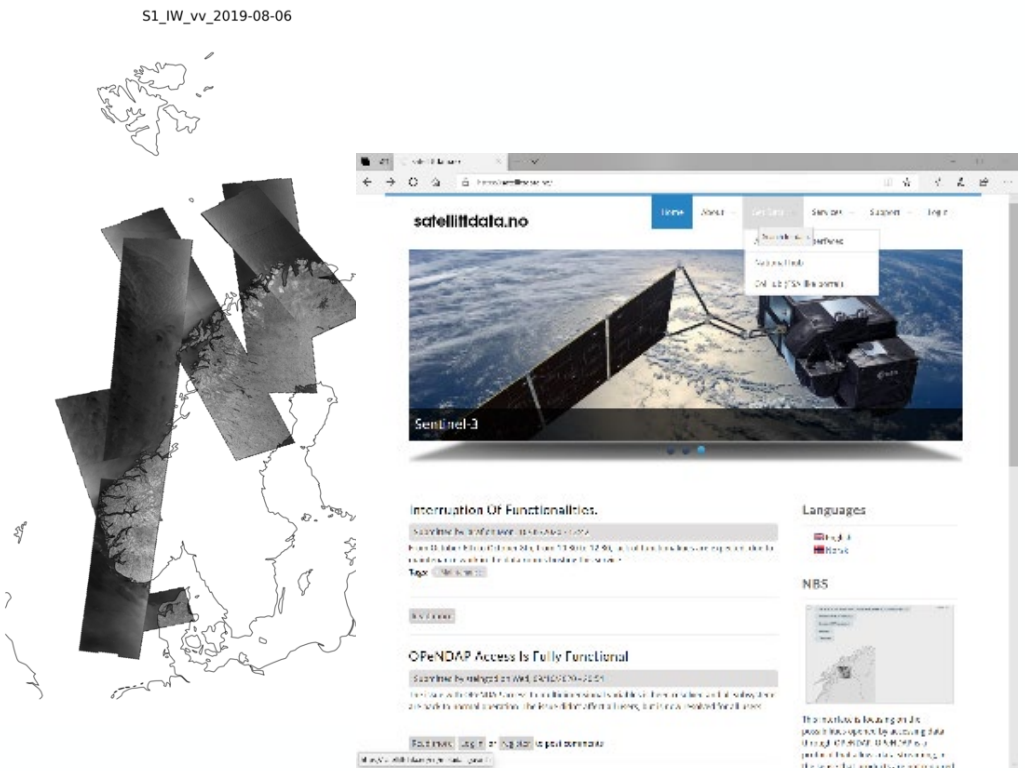
→ THE EUROPEAN SPACE AGENCY

InSAR.no: Norwegian ground motion service

- Launched Nov 29, 2018
- ~4000 scenes/year
- Over 5 billion measurement locations
- Updated yearly

http://insar.ngu.no
http://insar.no

Production

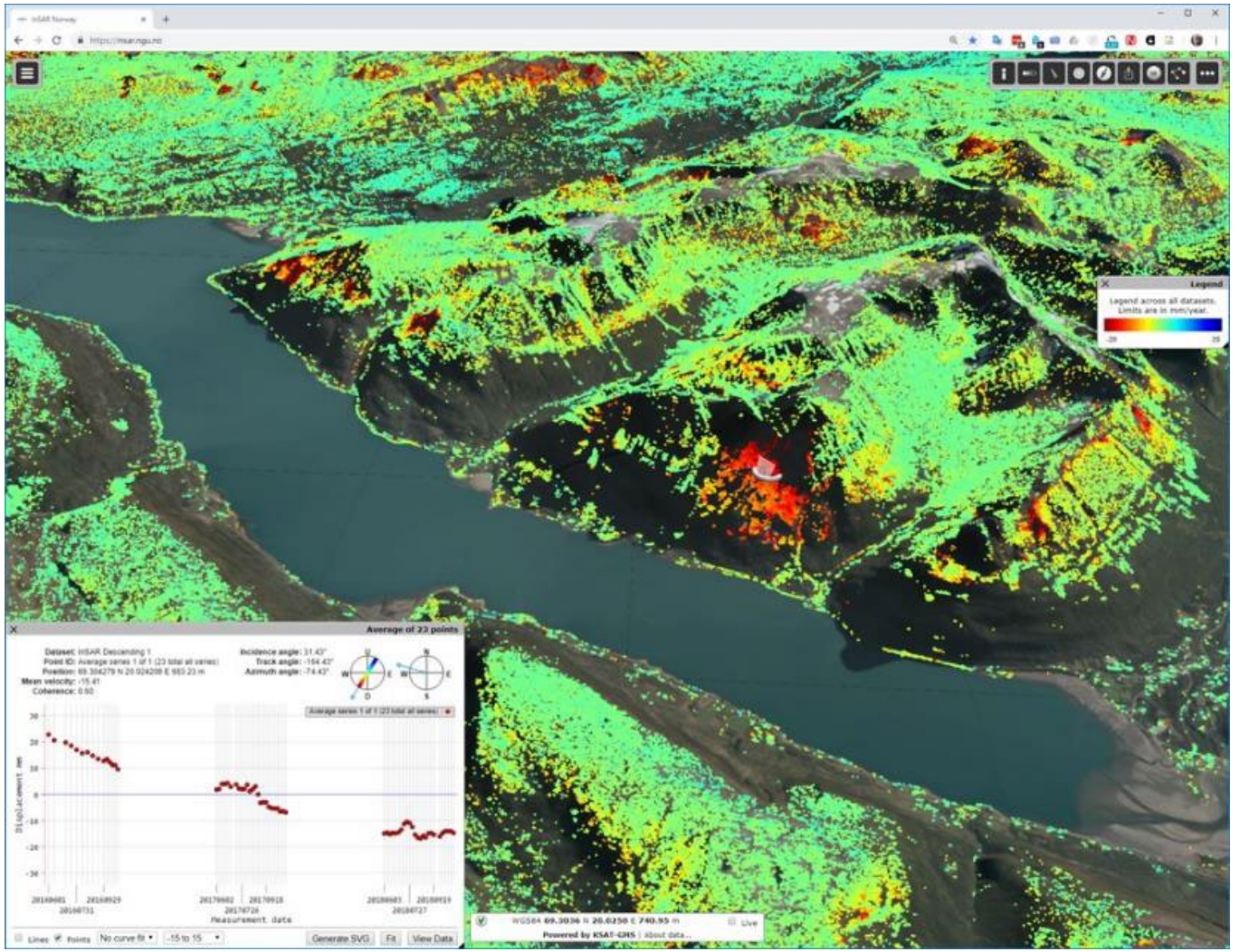


Nightly downloads via Norway Collaborative Ground Segment Hub, ~4000 scenes/year.

New images are continuously preprocessed in our HPCC and appended to existing data stacks, ready for final analysis.

Currently yearly updates.

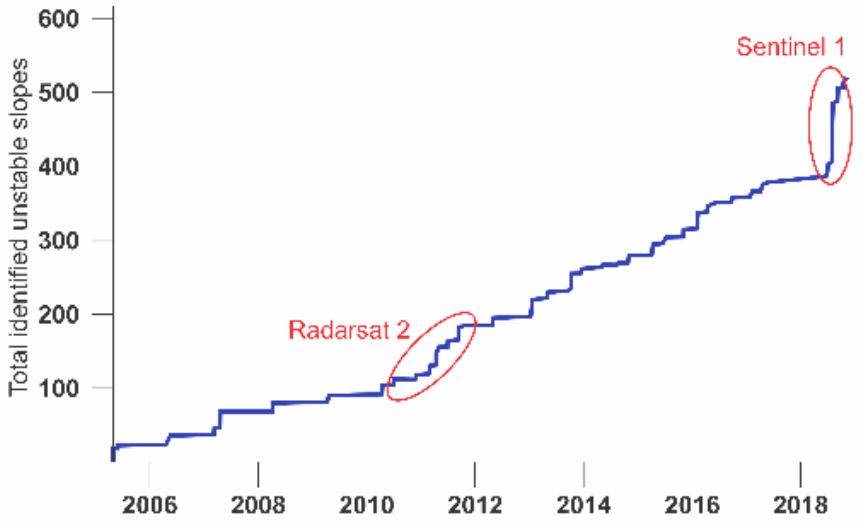
InSAR Norway – https://insar.ngu.no

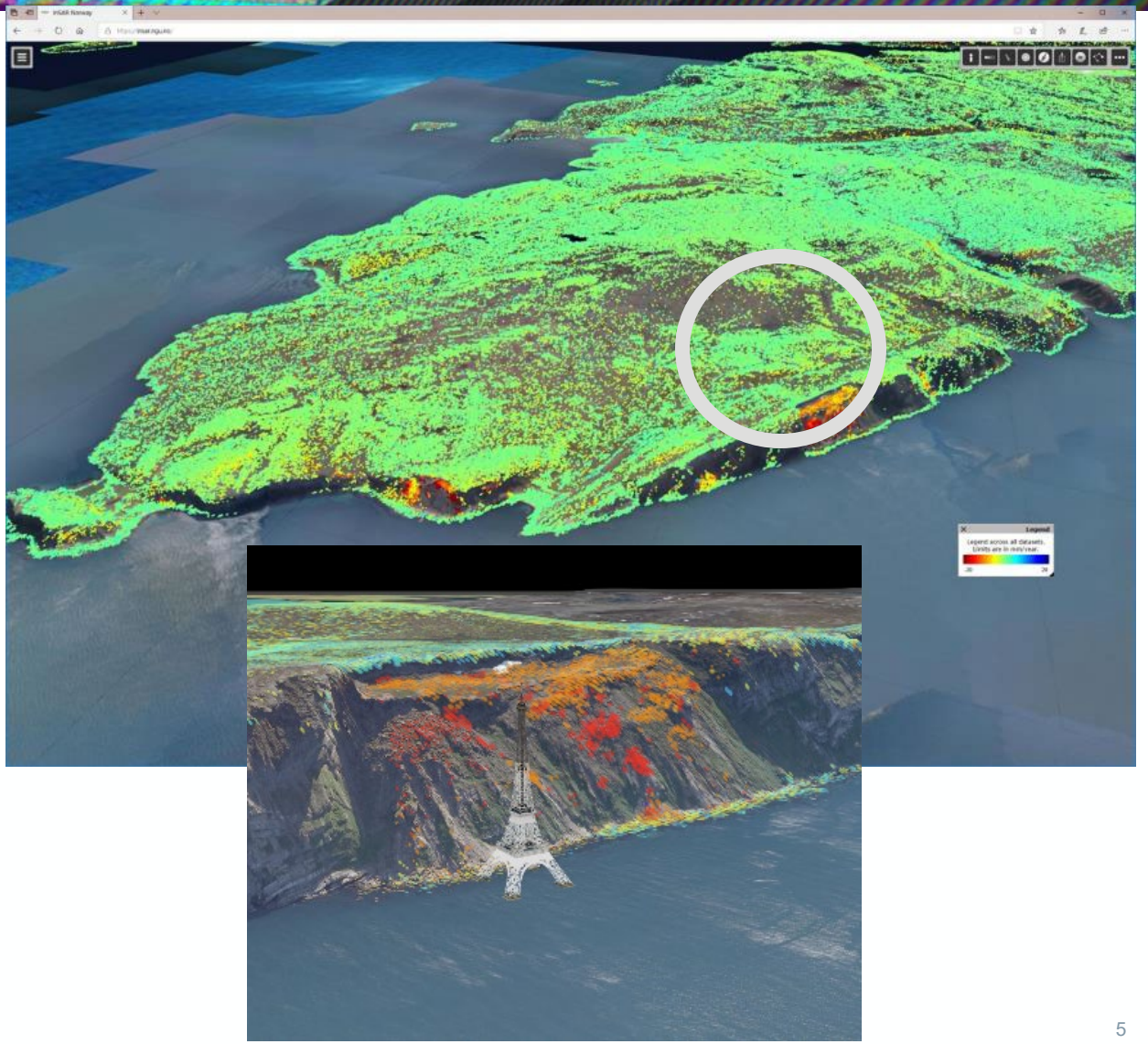


Mapping

InSAR has been an important first step for our systematic landslide mapping since we began doing widespread analysis of Radarsat-2 imagery.

Within one month of the release of our first nationwide Sentinel-1 based dataset in 2018, over 100 new unstable rockslopes were identified, such as this massive moving block along Porsangerfjord.





Hazard and risk

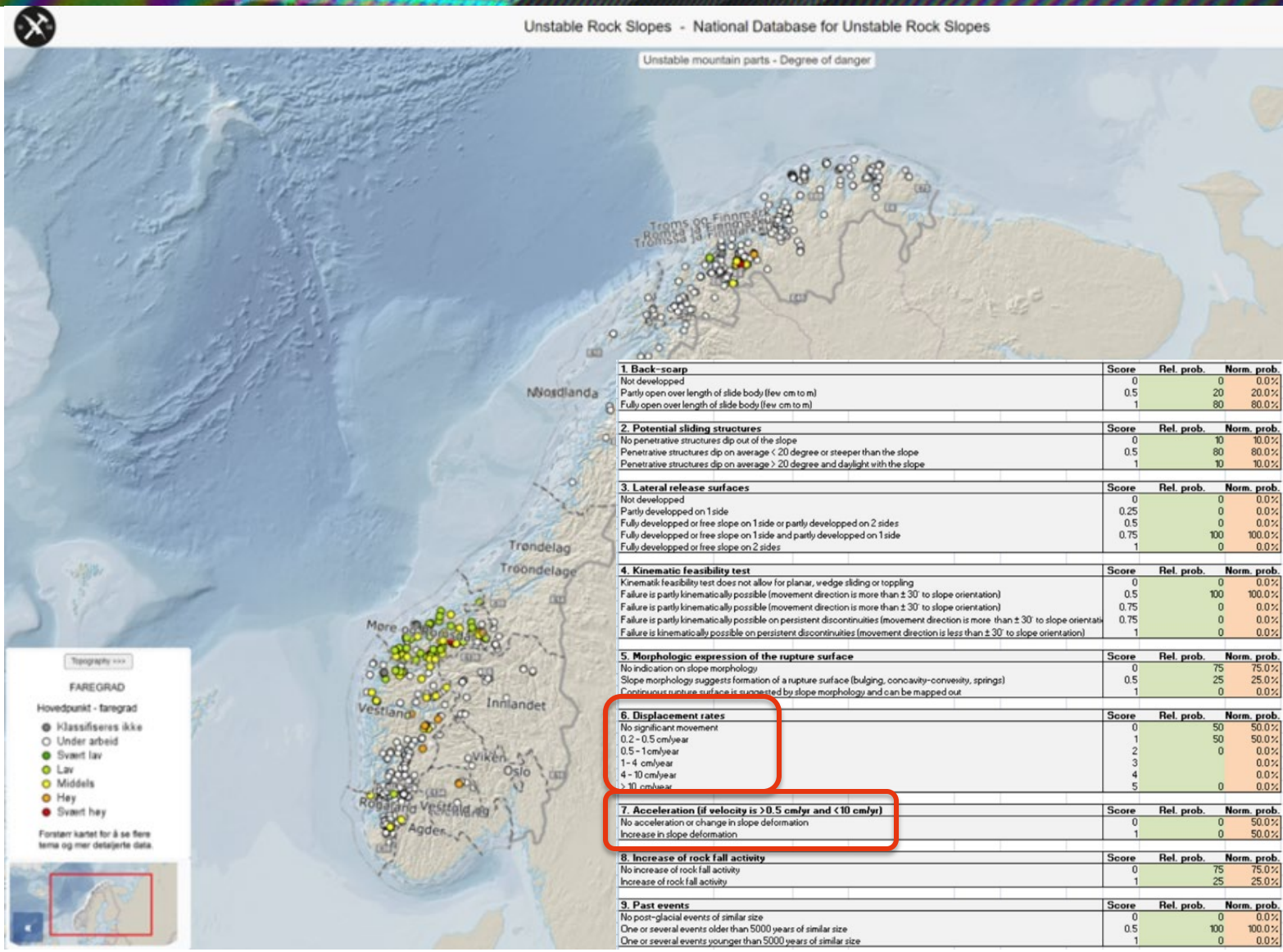
Over the years, more than 1000 sites have been identified.

For each site, a hazard and risk classification is performed to determine if permanent monitoring or other mitigation measures are necessary.

Measurements of displacement rates are a necessary component of the analysis.

10 sites are currently classified as high-risk, with permanent monitoring systems in place.

Numerous sites are classified as medium risk, with periodic monitoring.



1. Back-scarp	Score	Rel. prob.	Norm. prob.
Not developped	0	0	0.0%
Partly open over length of slide body (few cm to m)	0.5	20	20.0%
Fully open over length of slide body (few cm to m)	1	80	80.0%

2. Potential sliding structures	Score	Rel. prob.	Norm. prob.
No penetrative structures dip out of the slope	0	10	10.0%
Penetrative structures dip on average < 20 degree or steeper than the slope	0.5	80	80.0%
Penetrative structures dip on average > 20 degree and daylight with the slope	1	10	10.0%

3. Lateral release surfaces	Score	Rel. prob.	Norm. prob.
Not developped	0	0	0.0%
Partly developped on 1 side	0.25	0	0.0%
Fully developped or free slope on 1 side or partly developped on 2 sides	0.5	0	0.0%
Fully developped or free slope on 1 side and partly developped on 1 side	0.75	100	100.0%
Fully developped or free slope on 2 sides	1	0	0.0%

4. Kinematic feasibility test	Score	Rel. prob.	Norm. prob.
Kinematik feasibility test does not allow for planar, wedge sliding or toppling	0	0	0.0%
Failure is partly kinematically possible (movement direction is more than ± 30° to slope orientation)	0.5	100	100.0%
Failure is partly kinematically possible (movement direction is more than ± 30° to slope orientation)	0.75	0	0.0%
Failure is partly kinematically possible on persistent discontinuities (movement direction is more than ± 30° to slope orientati	0.75	0	0.0%
Failure is kinematically possible on persistent discontinuities (movement direction is less than ± 30° to slope orientation)	1	0	0.0%

5. Morphologic expression of the rupture surface	Score	Rel. prob.	Norm. prob.
No indication on slope morphology	0	75	75.0%
Slope morphology suggests formation of a rupture surface (bulging, concavity-convexity, springs)	0.5	25	25.0%
Continuous rupture surface is suggested by slope morphology and can be mapped out	1	0	0.0%

6. Displacement rates	Score	Rel. prob.	Norm. prob.
No significant movement	0	50	50.0%
0.2 - 0.5 cm/year	1	50	50.0%
0.5 - 1 cm/year	2	0	0.0%
1 - 4 cm/year	3		0.0%
4 - 10 cm/year	4		0.0%
> 10 cm/year	5	0	0.0%

7. Acceleration (if velocity is >0.5 cm/yr and <10 cm/yr)	Score	Rel. prob.	Norm. prob.
No acceleration or change in slope deformation	0	0	50.0%
Increase in slope deformation	1	0	50.0%

8. Increase of rock fall activity	Score	Rel. prob.	Norm. prob.
No increase of rock fall activity	0	75	75.0%
Increase of rock fall activity	1	25	25.0%

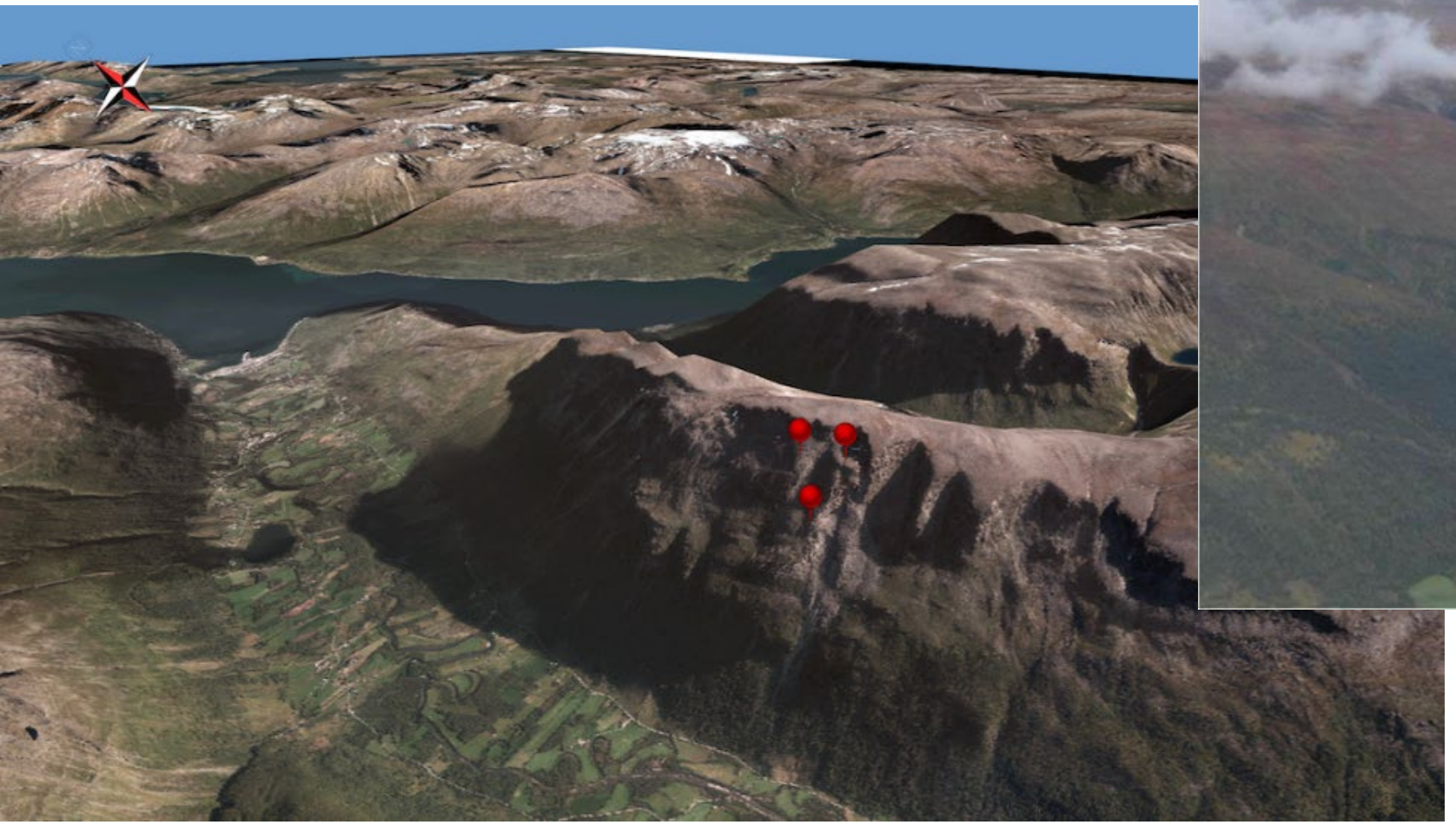
9. Past events	Score	Rel. prob.	Norm. prob.
No post-glacial events of similar size	0	0	0.0%
One or several events older than 5000 years of similar size	0.5	100	100.0%
One or several events younger than 5000 years of similar size	1	0	0.0%

Corner reflectors – Operational landslide monitoring

At all high-risk sites, and numerous others, we have installed networks of corner reflectors that stand above the snow, to get InSAR data during the winter months.

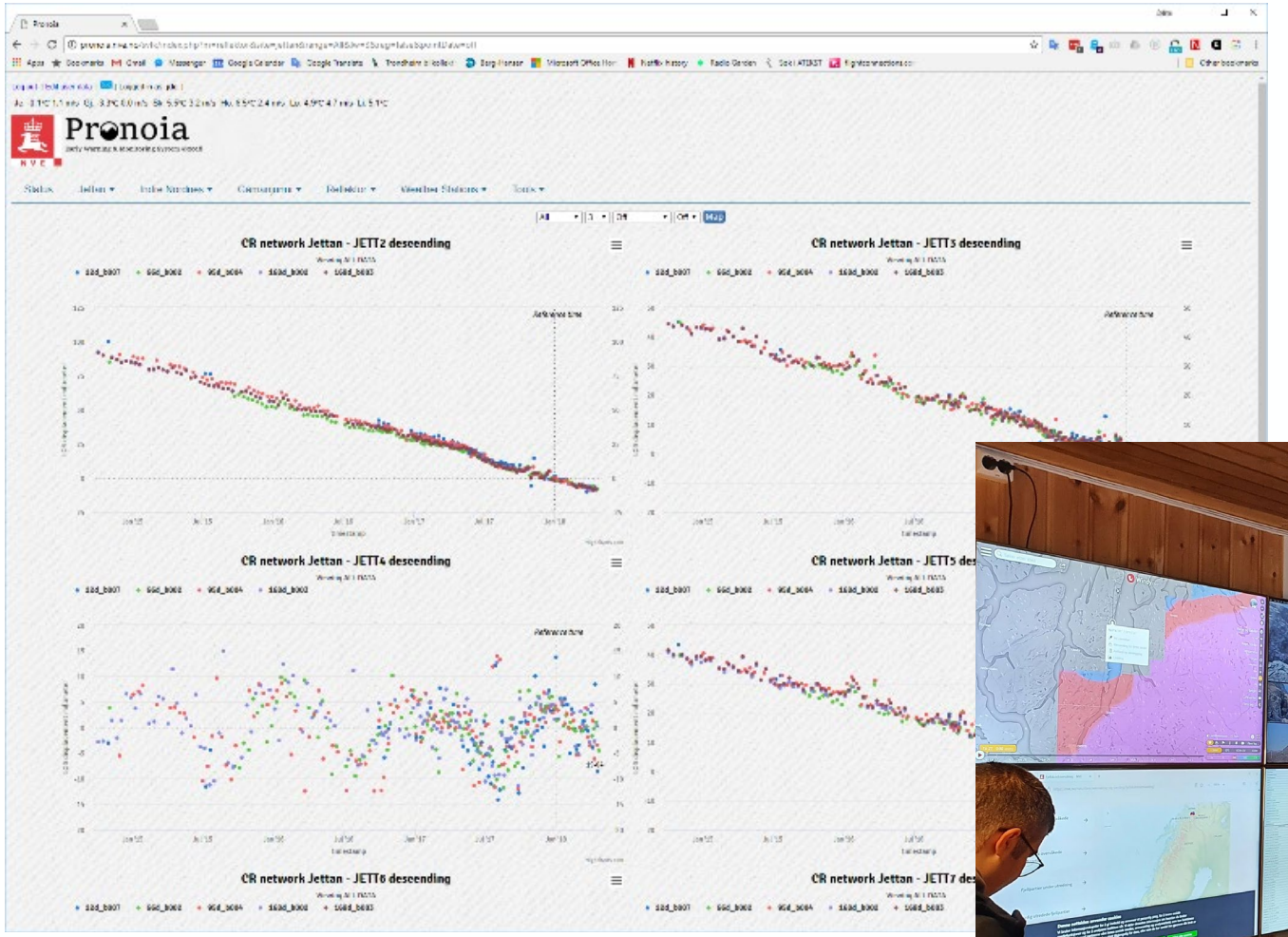
More than 120 reflectors are now in use at over 25 locations.

Corner reflectors

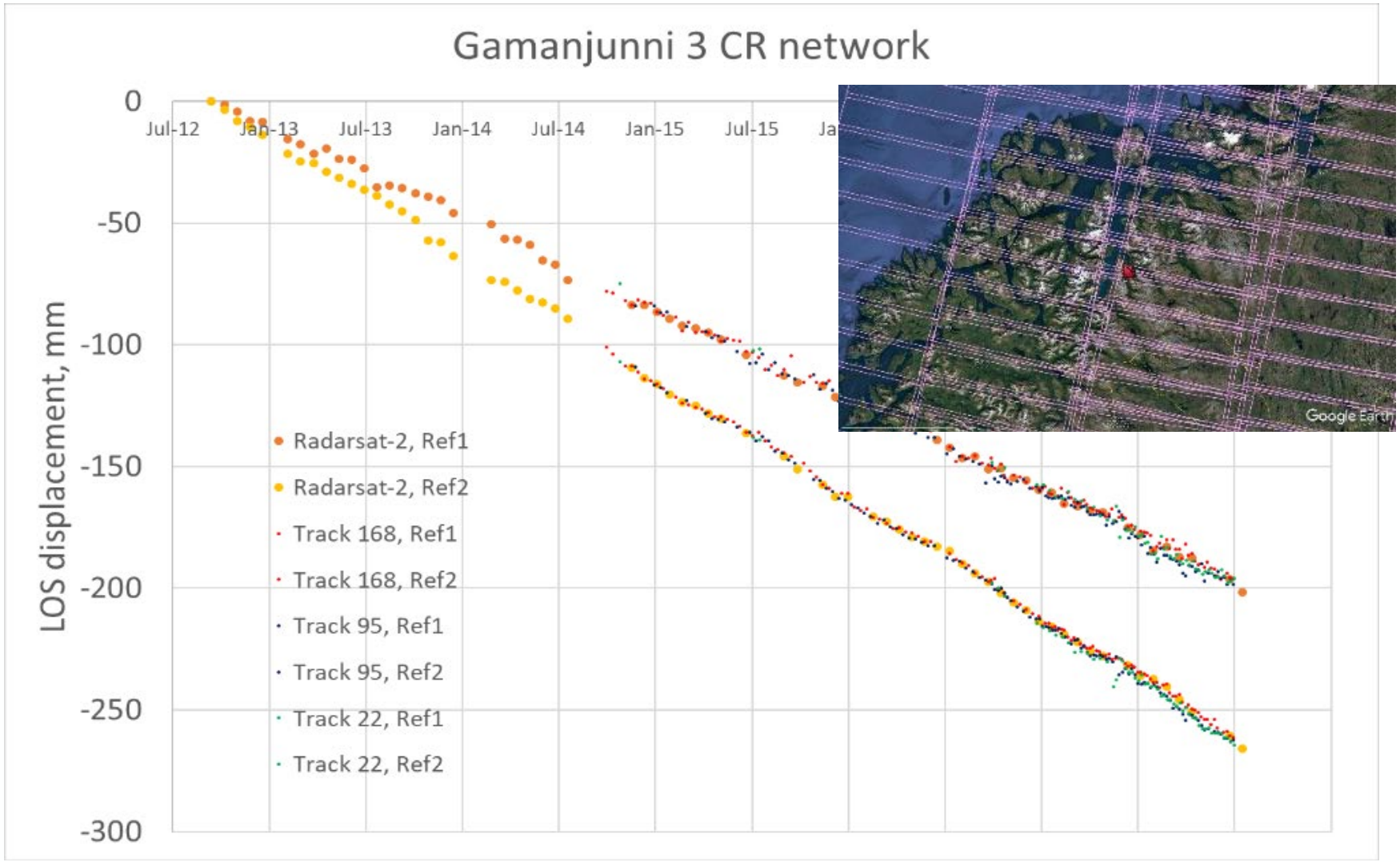


Corner reflectors

All corner reflector networks are processed automatically nightly and updated time series are transferred to our permanent monitoring system. Other in-situ instruments in the same system.




S1_IW_vv_2019-08-06

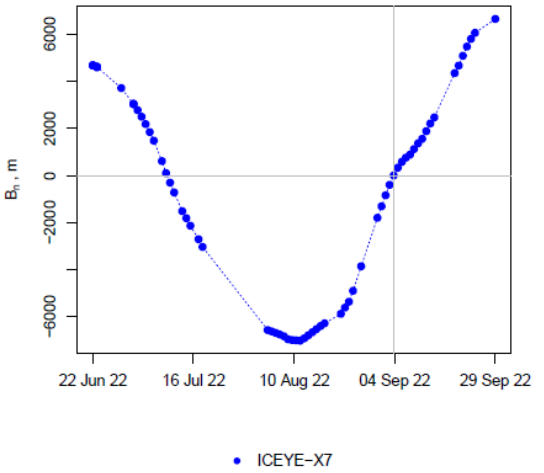

Gamanjunni 3 CR network
LOS displacement, mm
0
-50
-100
-150
-200
-250
-300
Jul-12
Jan-13
Jul-13
Jan-14
Jul-14
Jan-15
Jul-15
Radarsat-2, Ref1
Radarsat-2, Ref2
Track 168, Ref1
Track 168, Ref2
Track 95, Ref1
Track 95, Ref2
Track 22, Ref1
Track 22, Ref2
Google Earth

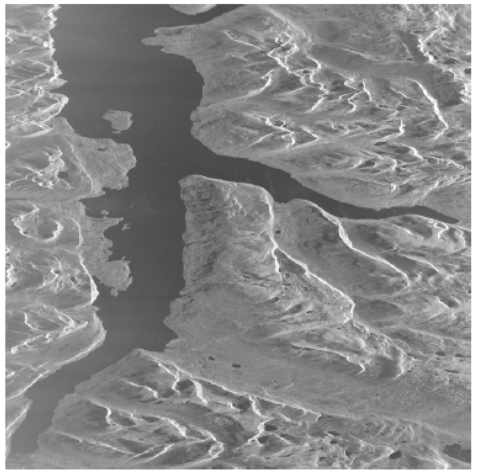
Iceye pilot - data

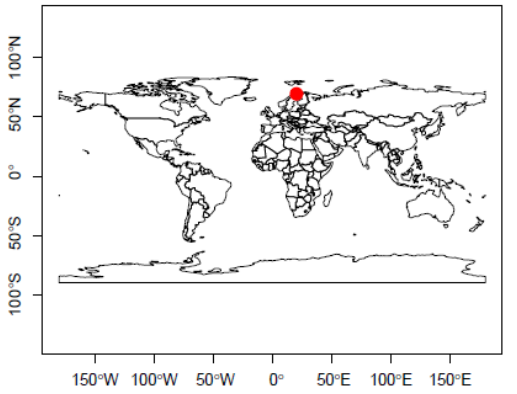
The loss of redundancy due to the failure of Sentinel-1B led us to supplement some sites with commercial data. At the same time, we wished to look into the potential provided by ICEYE's very short revisit in the case of future emergencies.

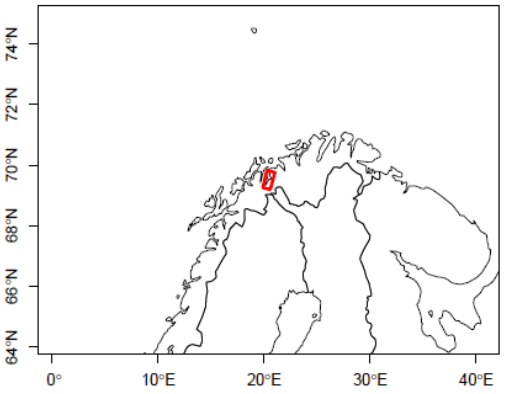
The area around Nordnes, in northern Norway was chosen due to the high number of instrumented moving slopes with CR networks.

58 Strip-mode images were acquired between June 22 and September 29, 2022, totalling 99 days of coverage. The gaps were due to occasional orbital manoeuvres and commercial availability.









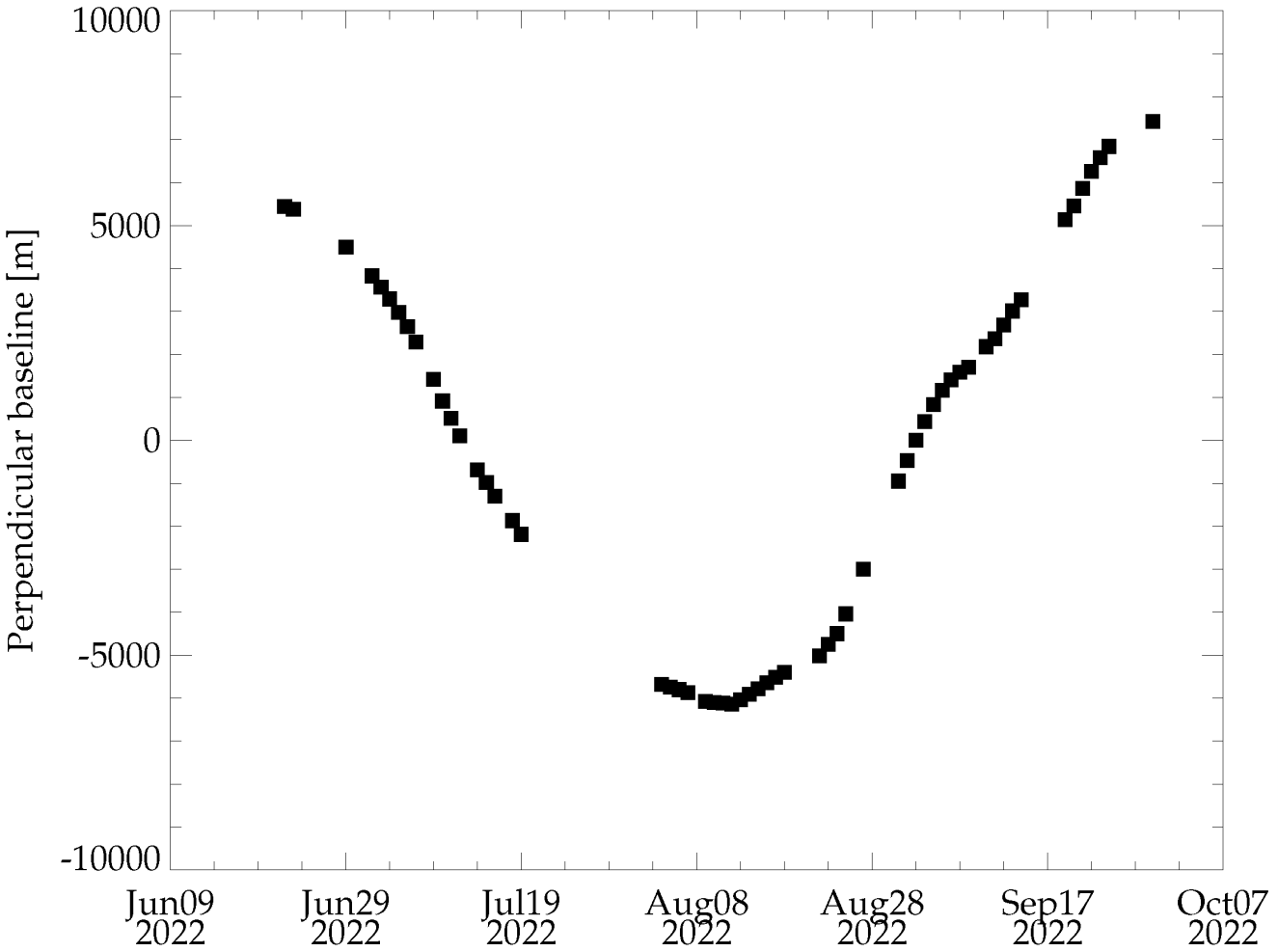
stack	stack size	id	run name	frame	product type	duration, days	Bn min, m	Bn max, m	Bn min full graph, m
1/1	60	1082017	default	1	stripmap	99	13	3553	3

Iceye - location

Iceye – processing challenges

Main challenges

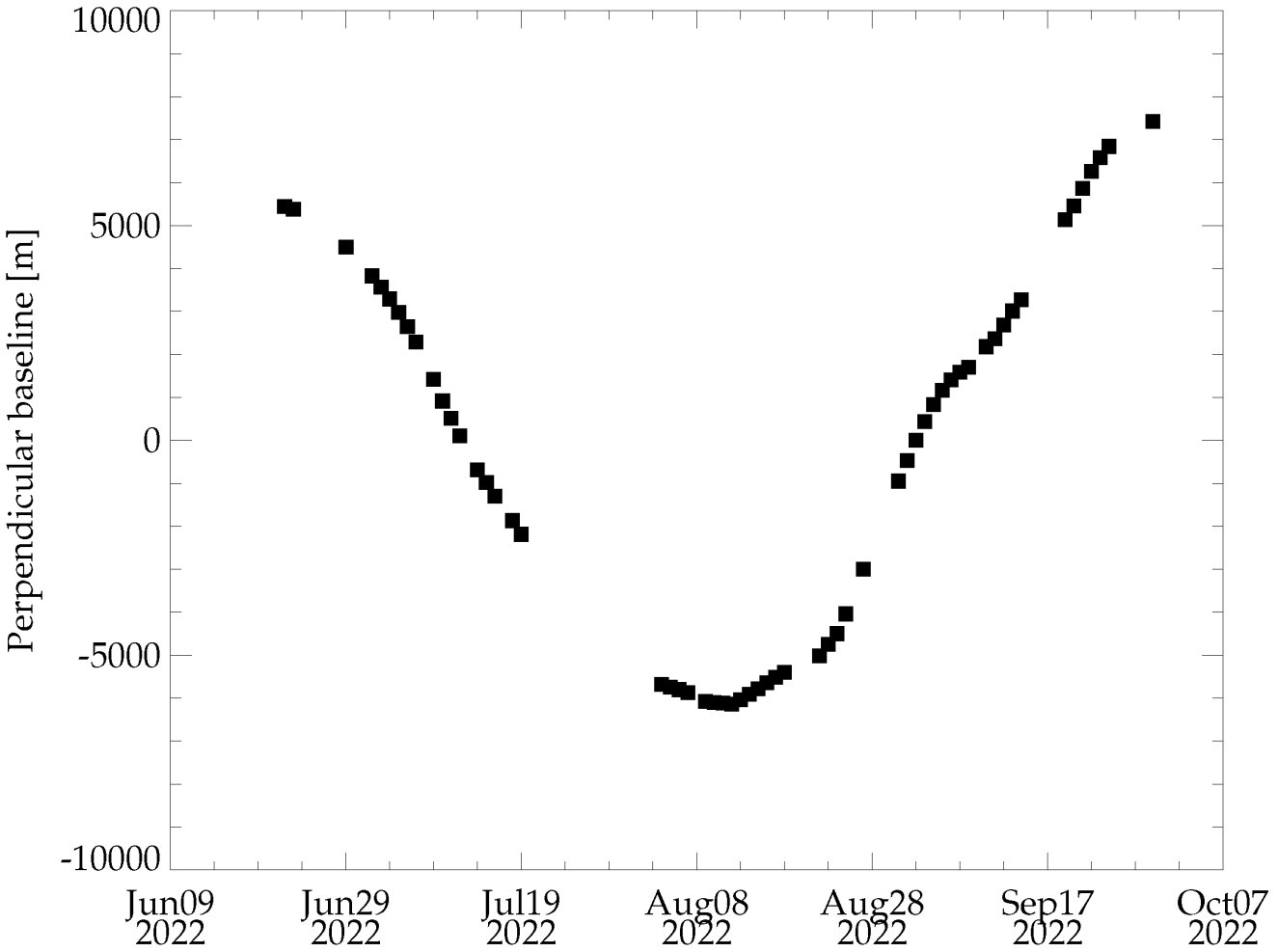
- Orbit characteristics (very long baselines)
- Orbit quality



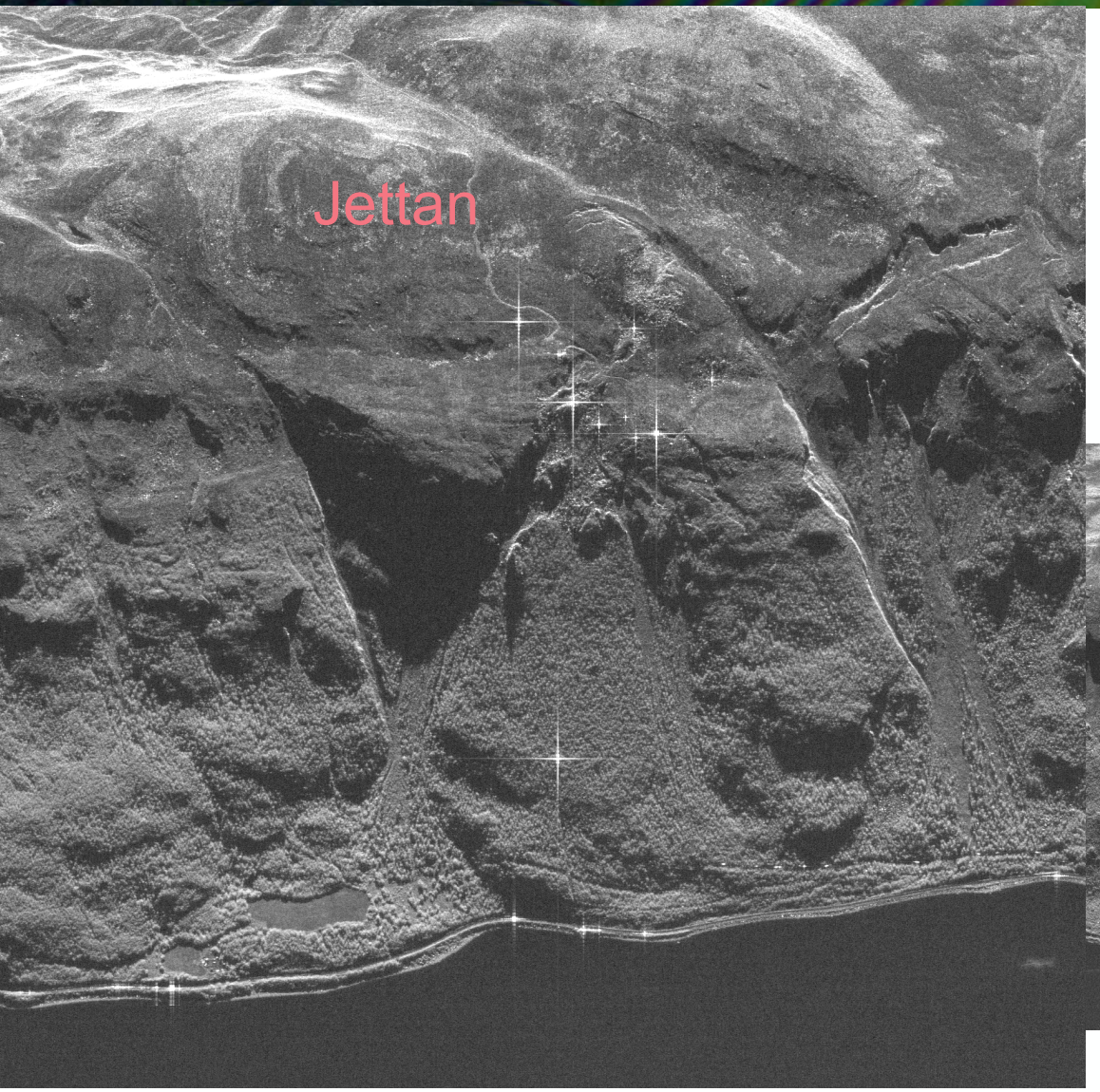
Iceye – orbit characteristics

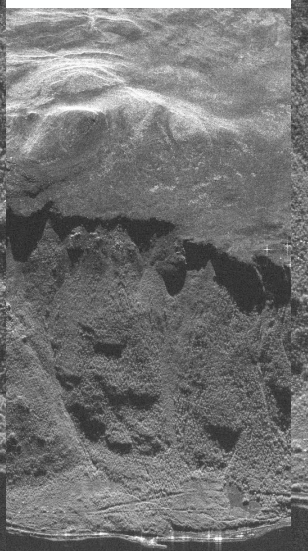
The long baselines require the use of a DEM in the coregistration of SLCs.

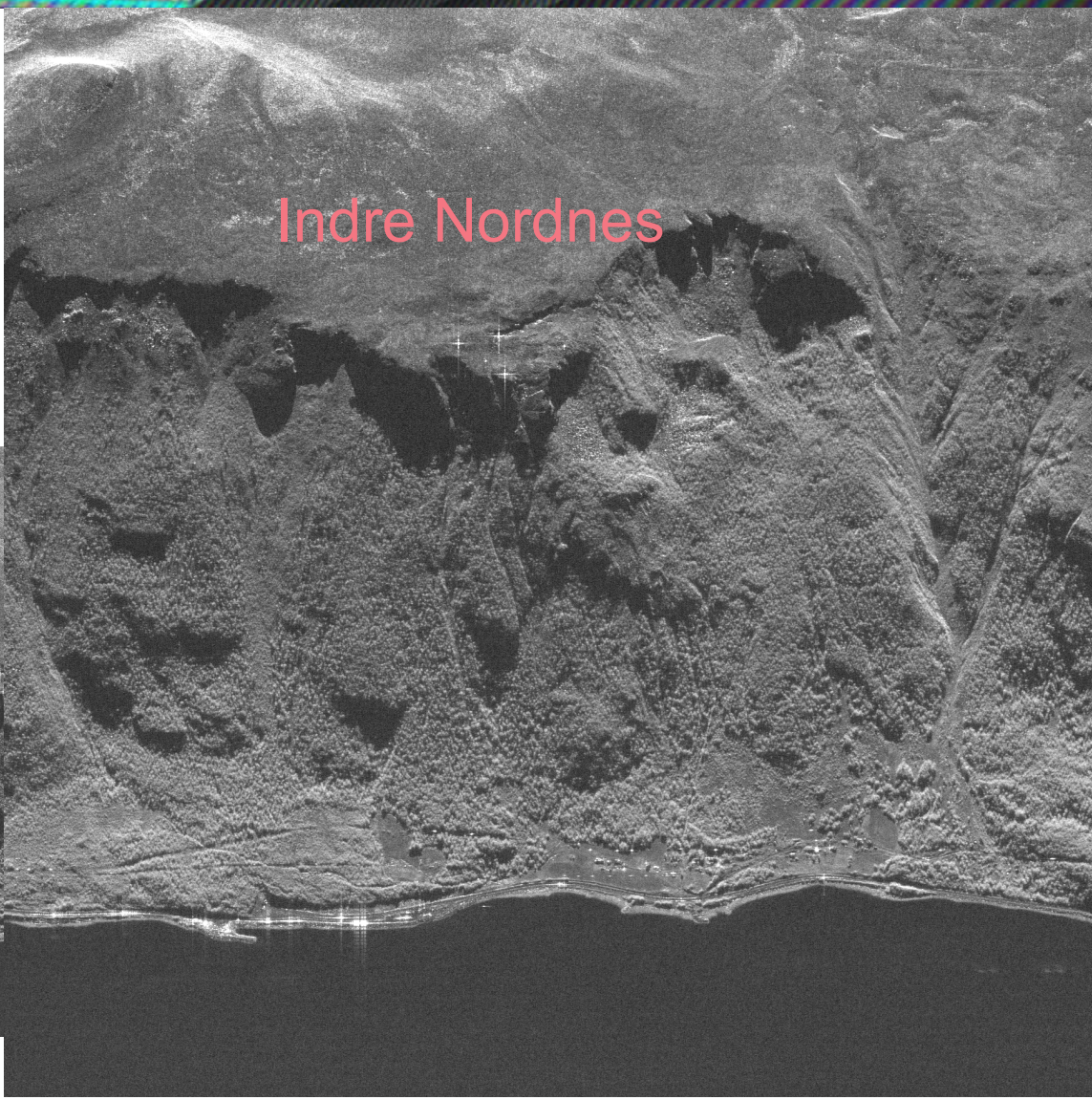
The baseline is temporally correlated
→ full orbital drift cycle is needed for proper time series processing



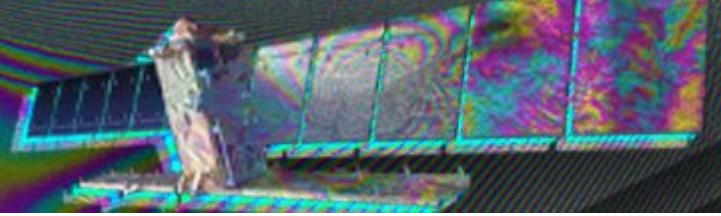
Iceye – processing challenges





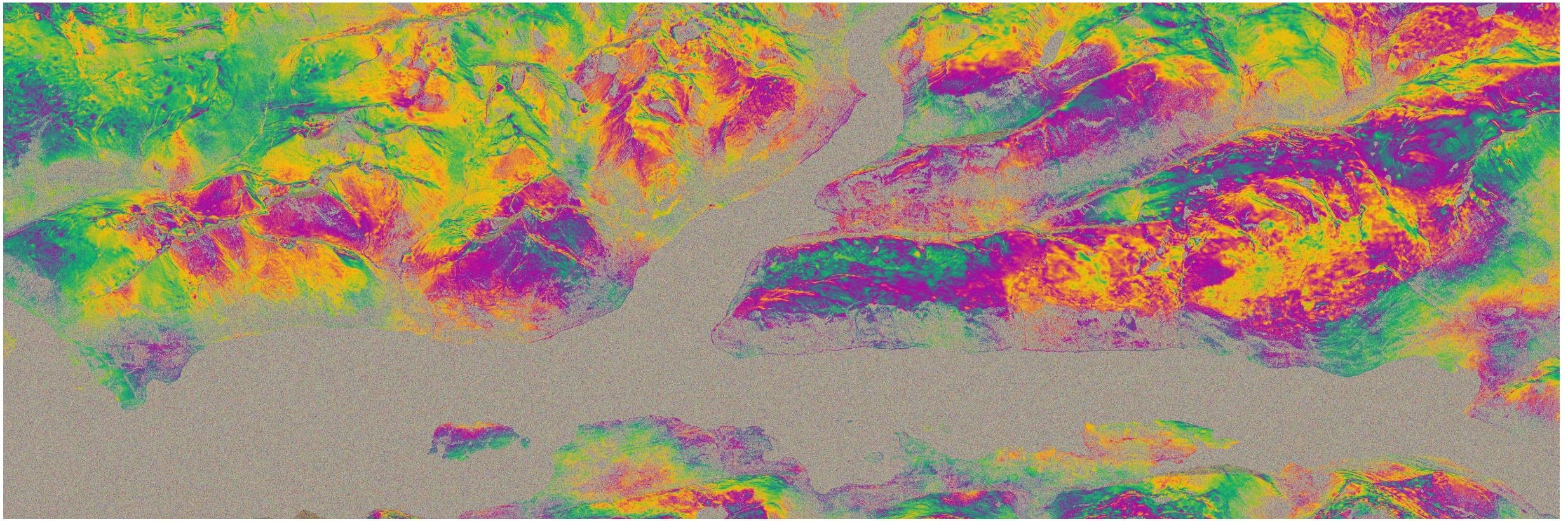


Iceye – orbit quality



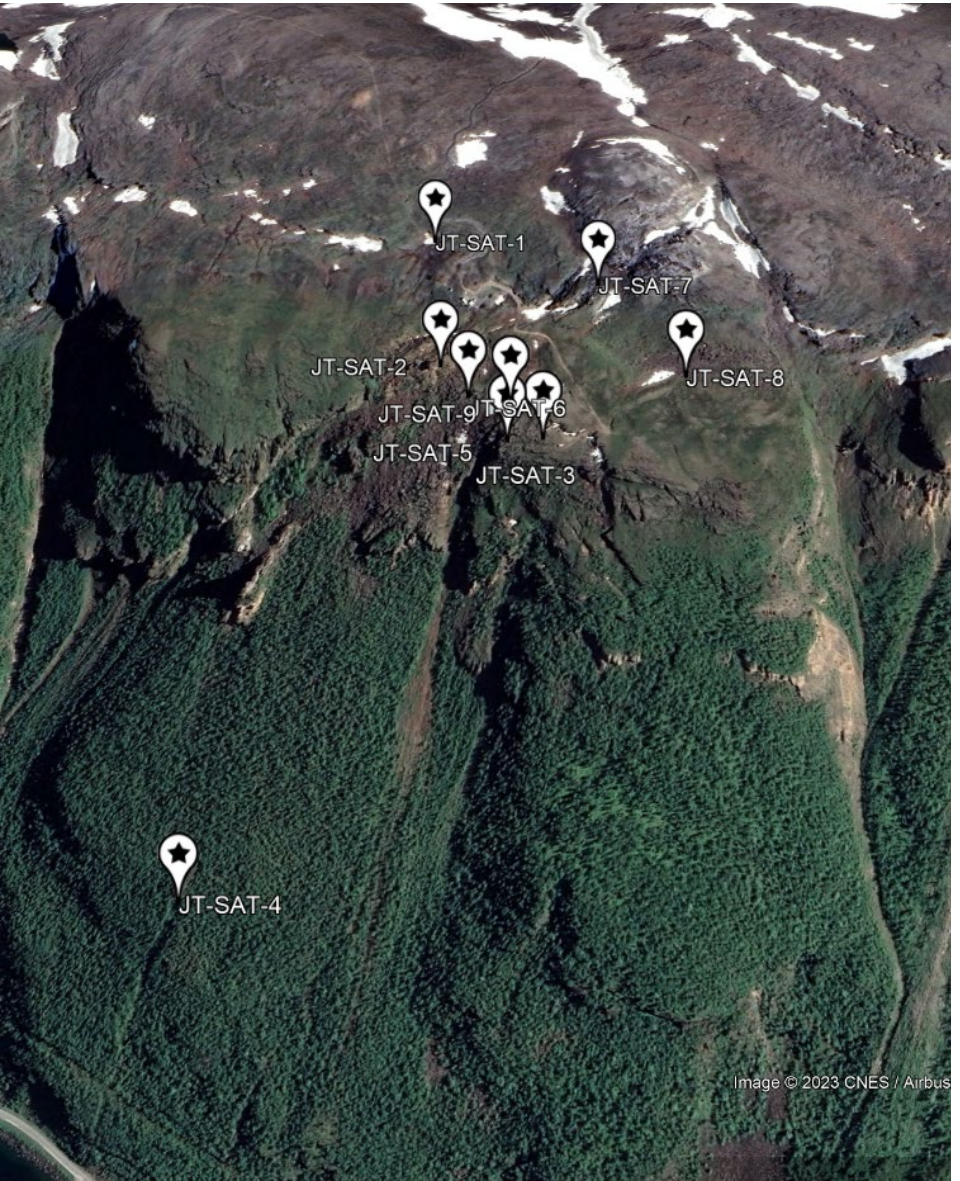
- Large errors (>10m) in annotated orbits.
- The absolute positioning error of the reference scene must be within few meters in areas with large topographic variations
- ~20 CRs available in the AOI
- **Summary of stack coregistration approach**
  - Correction of reference scene orbit using CRs
  - first order orbit correction for the rest of the stack using CRs
  - Residual orbit correction using a classical patch correlation method
  - DEM assisted geometric coregistration

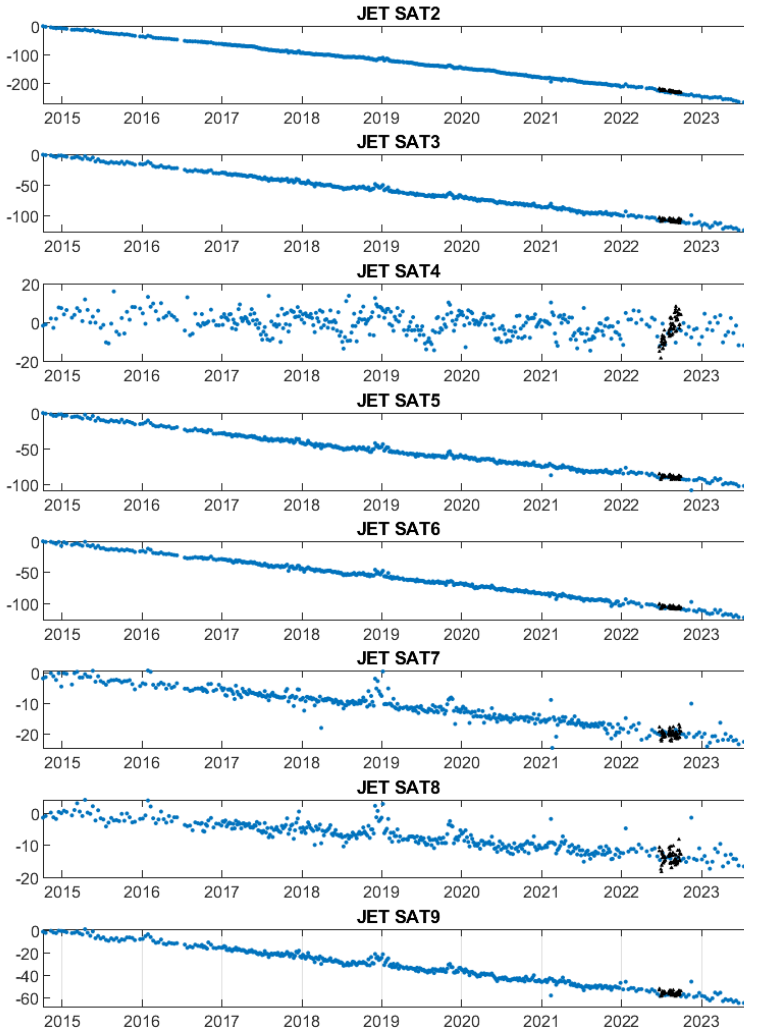
Iceye - processing

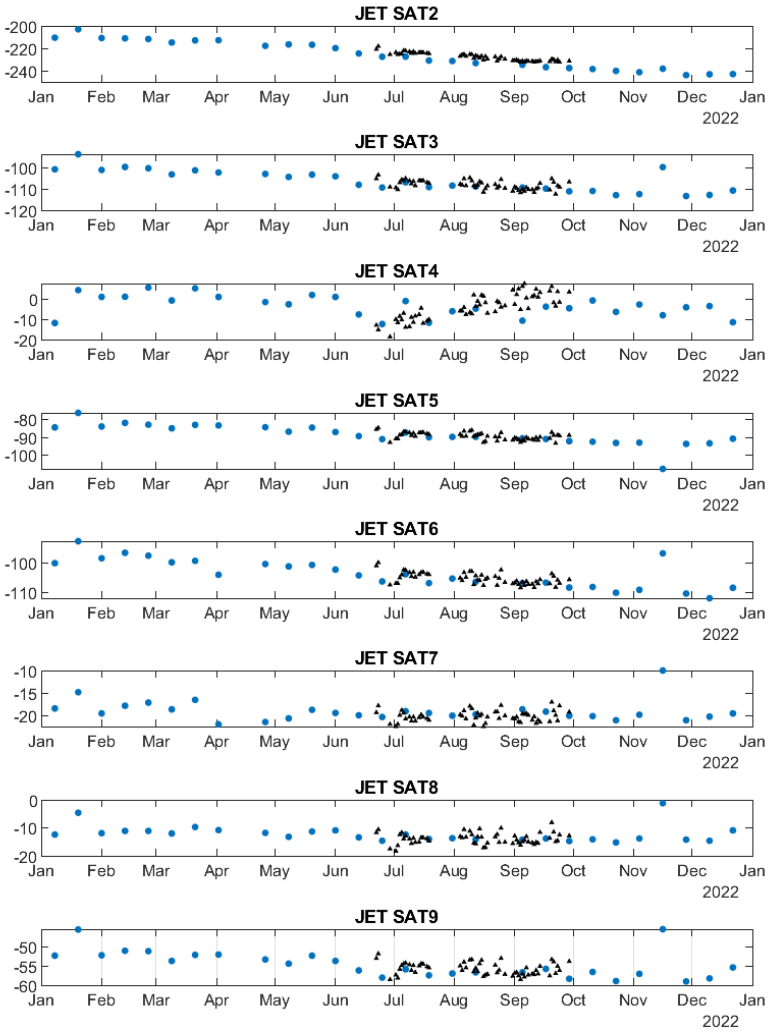


One day interferogram (06.09.2022 – 07.09.2022), 6x6 multilook

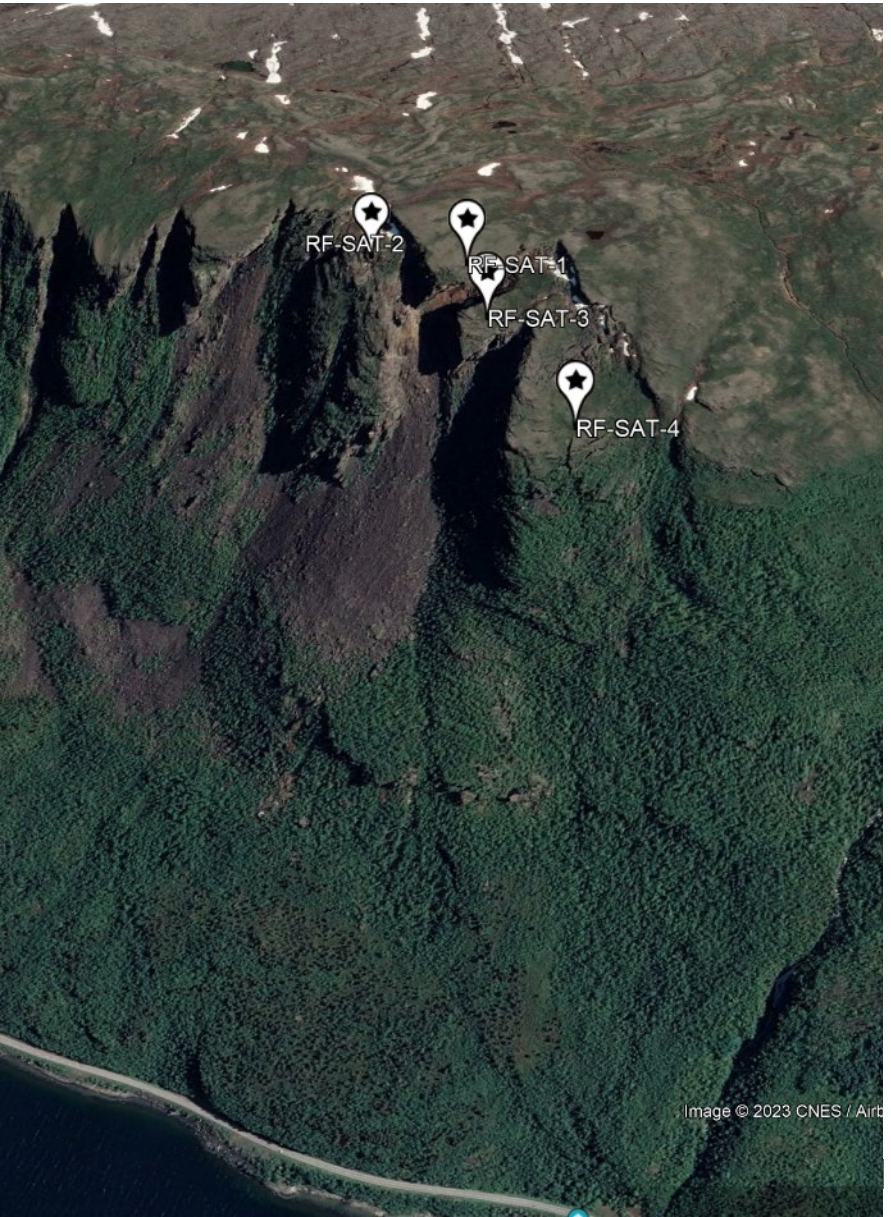
Jettan

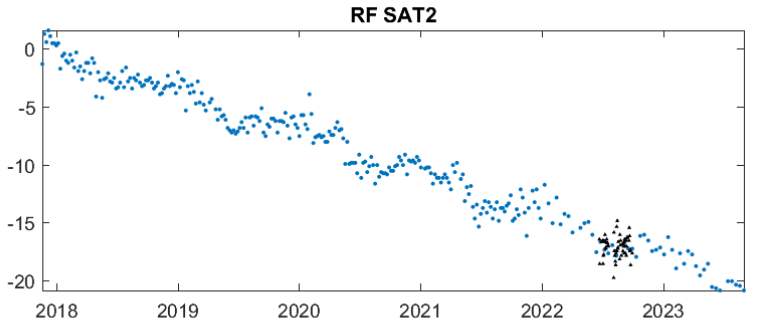

JT-SAT-1
JT-SAT-7
JT-SAT-2
JT-SAT-8
JT-SAT-9
JT-SAT-6
JT-SAT-5
JT-SAT-3
JT-SAT-4
Image © 2023 CNES / Airbus

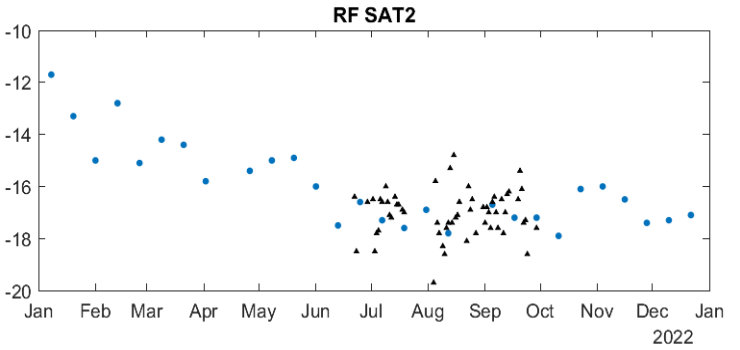

JET SAT2
JET SAT3
JET SAT4
JET SAT5
JET SAT6
JET SAT7
JET SAT8
JET SAT9
2015
2016
2017
2018
2019
2020
2021
2022
2023

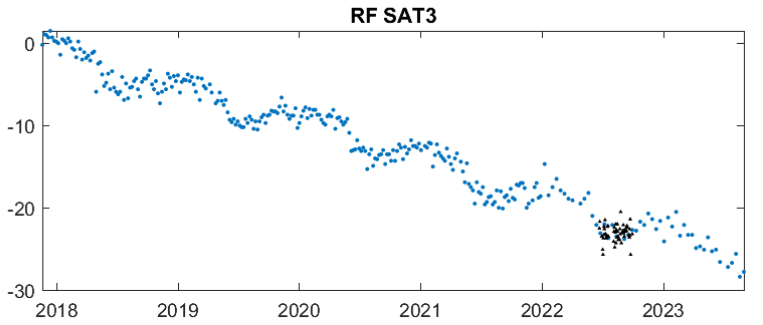

JET SAT2
JET SAT3
JET SAT4
JET SAT5
JET SAT6
JET SAT7
JET SAT8
JET SAT9
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2022

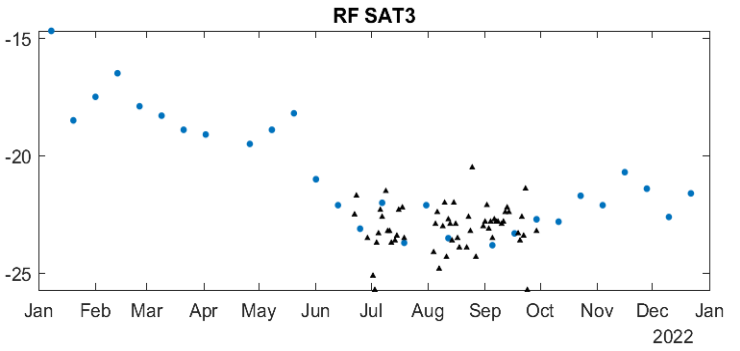
Revdalsfjellet

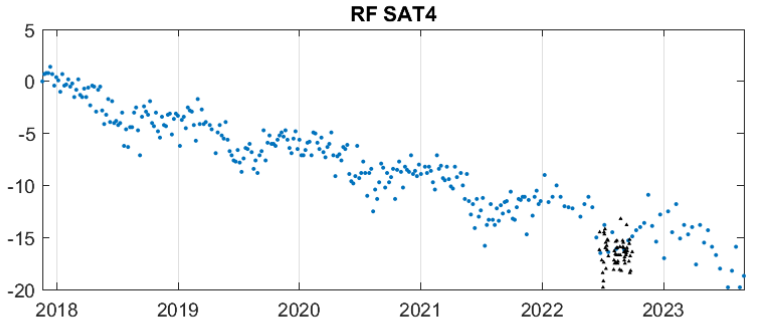


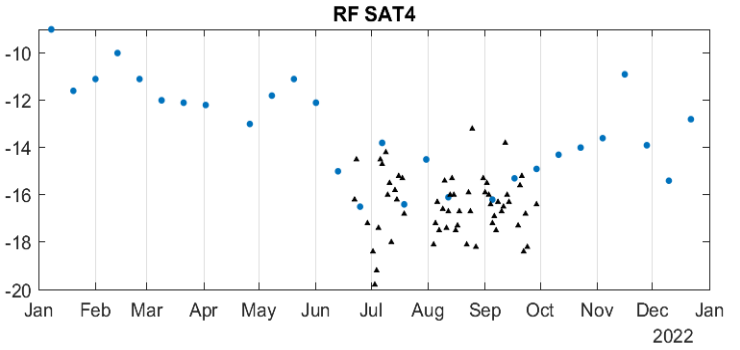




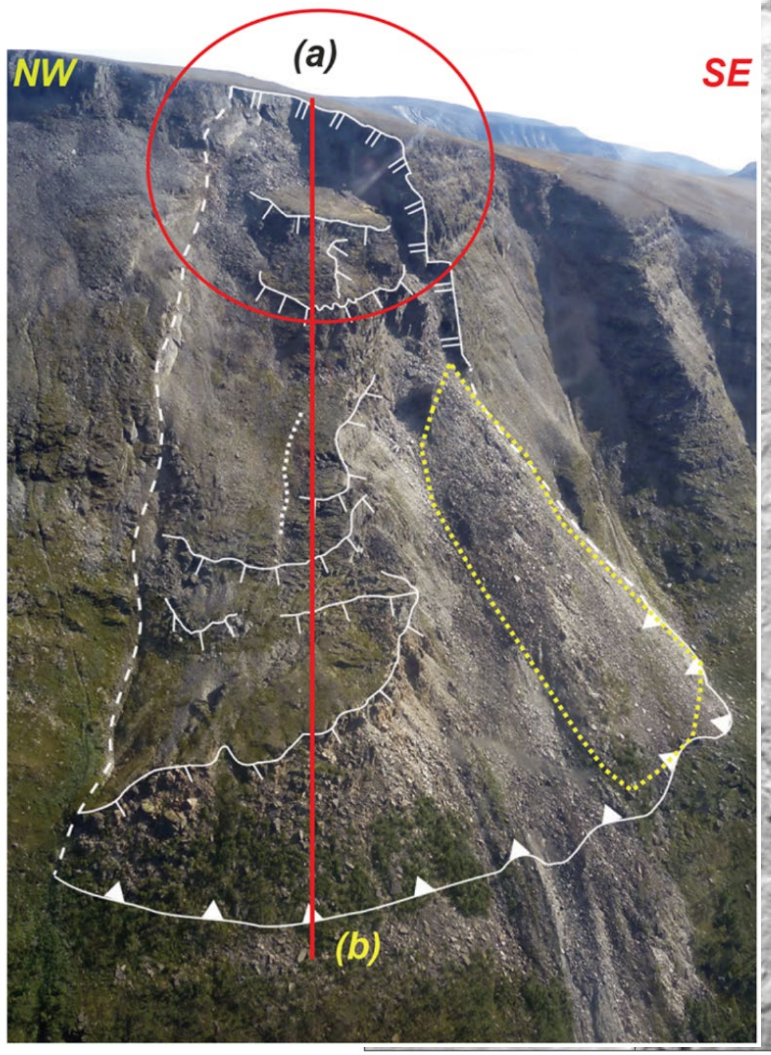


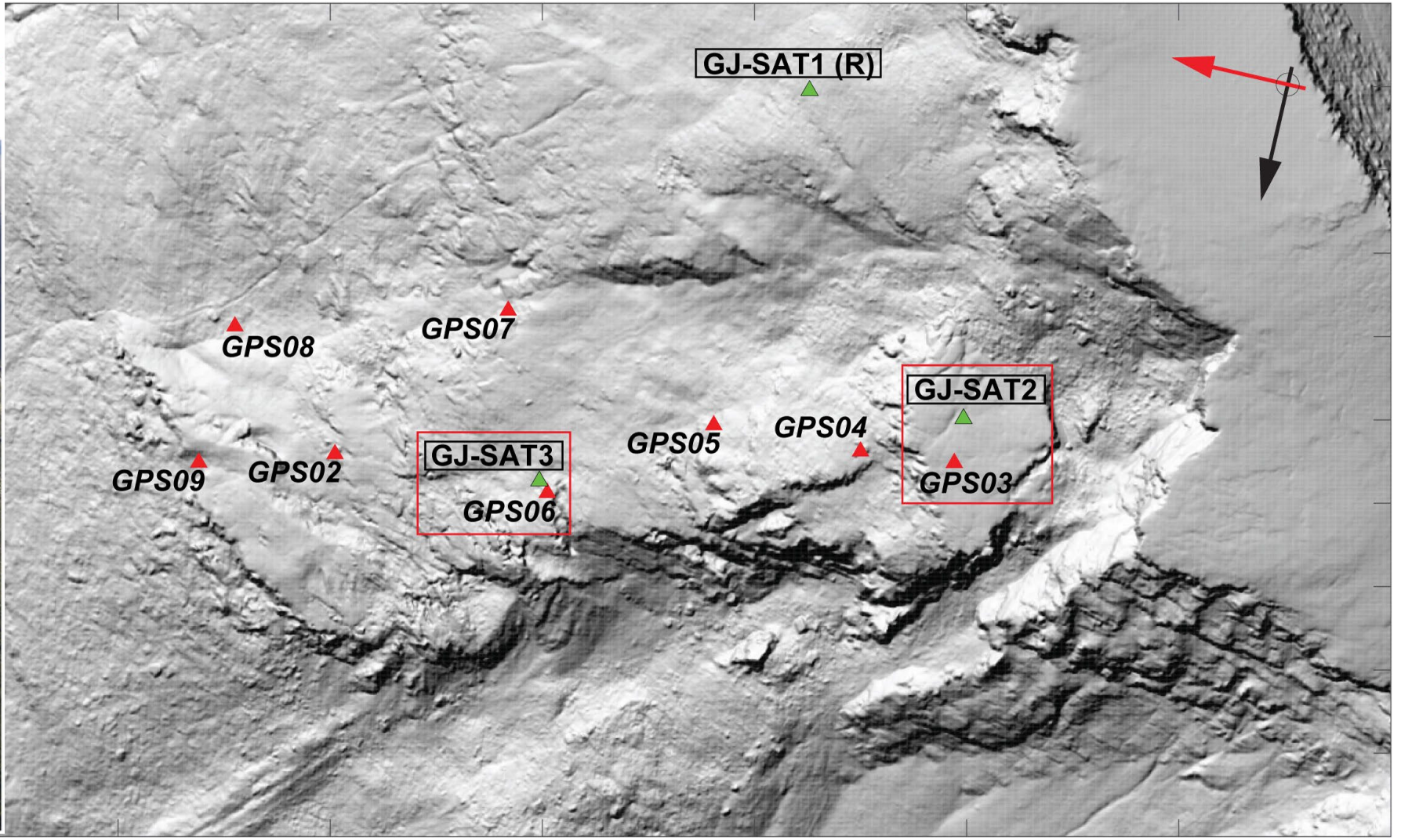






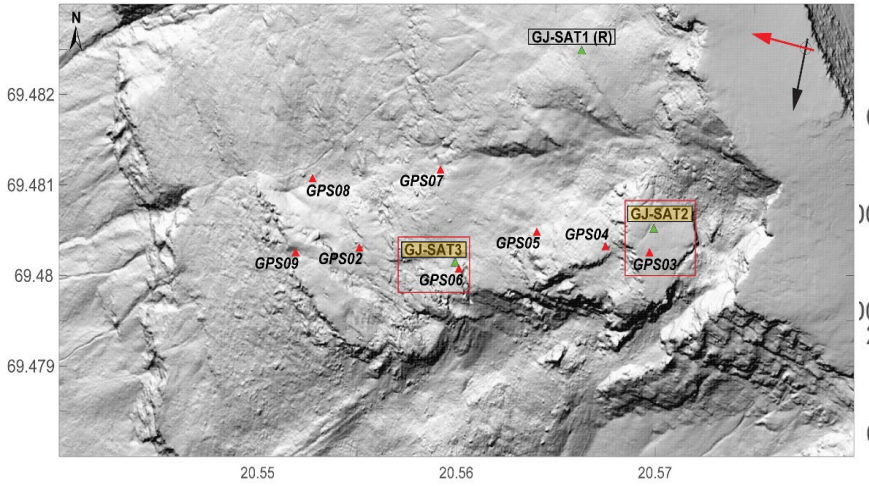
Gamanjunni

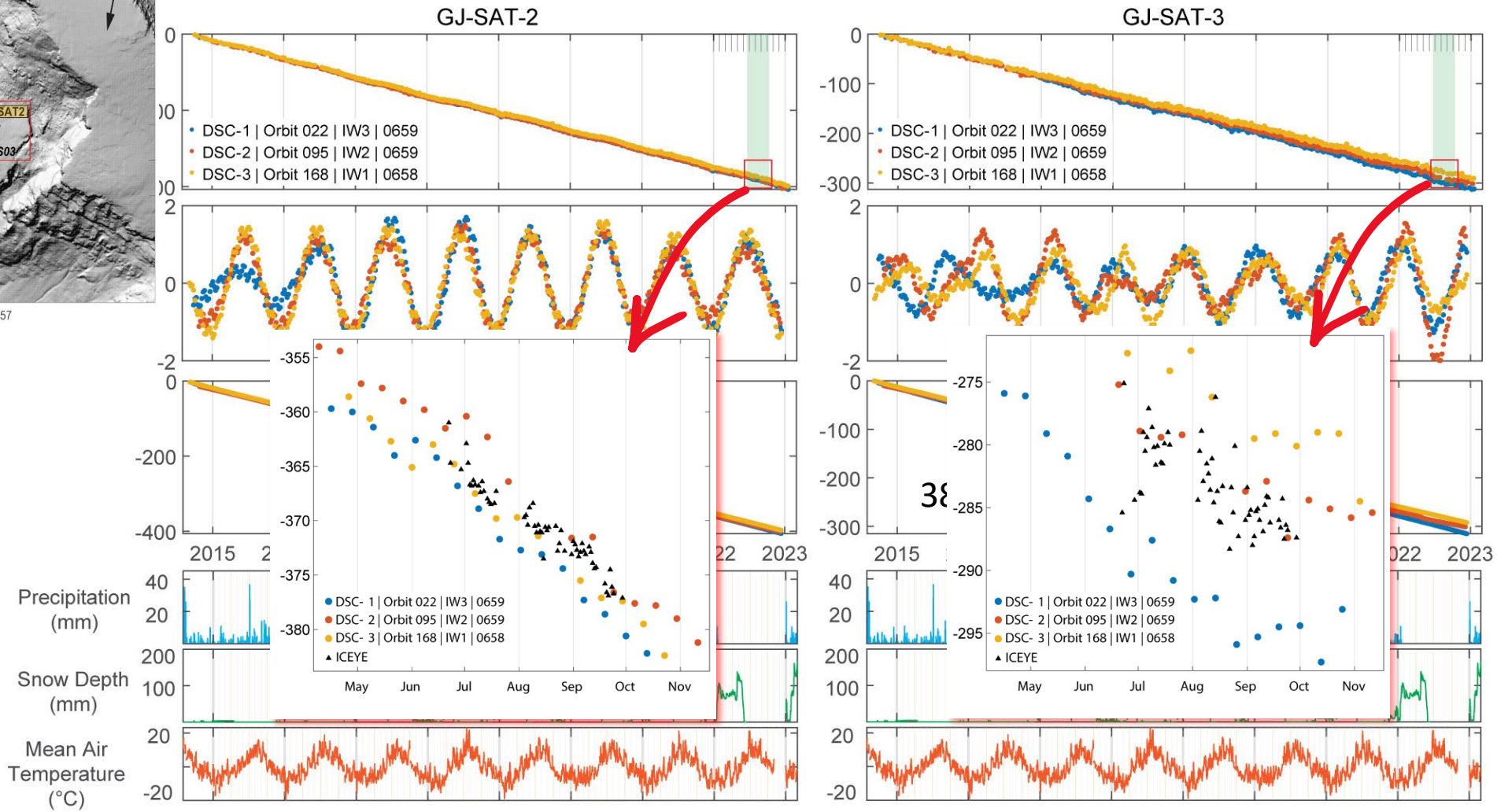

NW
SE
(a)
(b)


GJ-SAT1 (R)
GPS08
GPS07
GJ-SAT2
GPS04
GPS05
GJ-SAT3
GPS09
GPS02
GPS03
GPS06

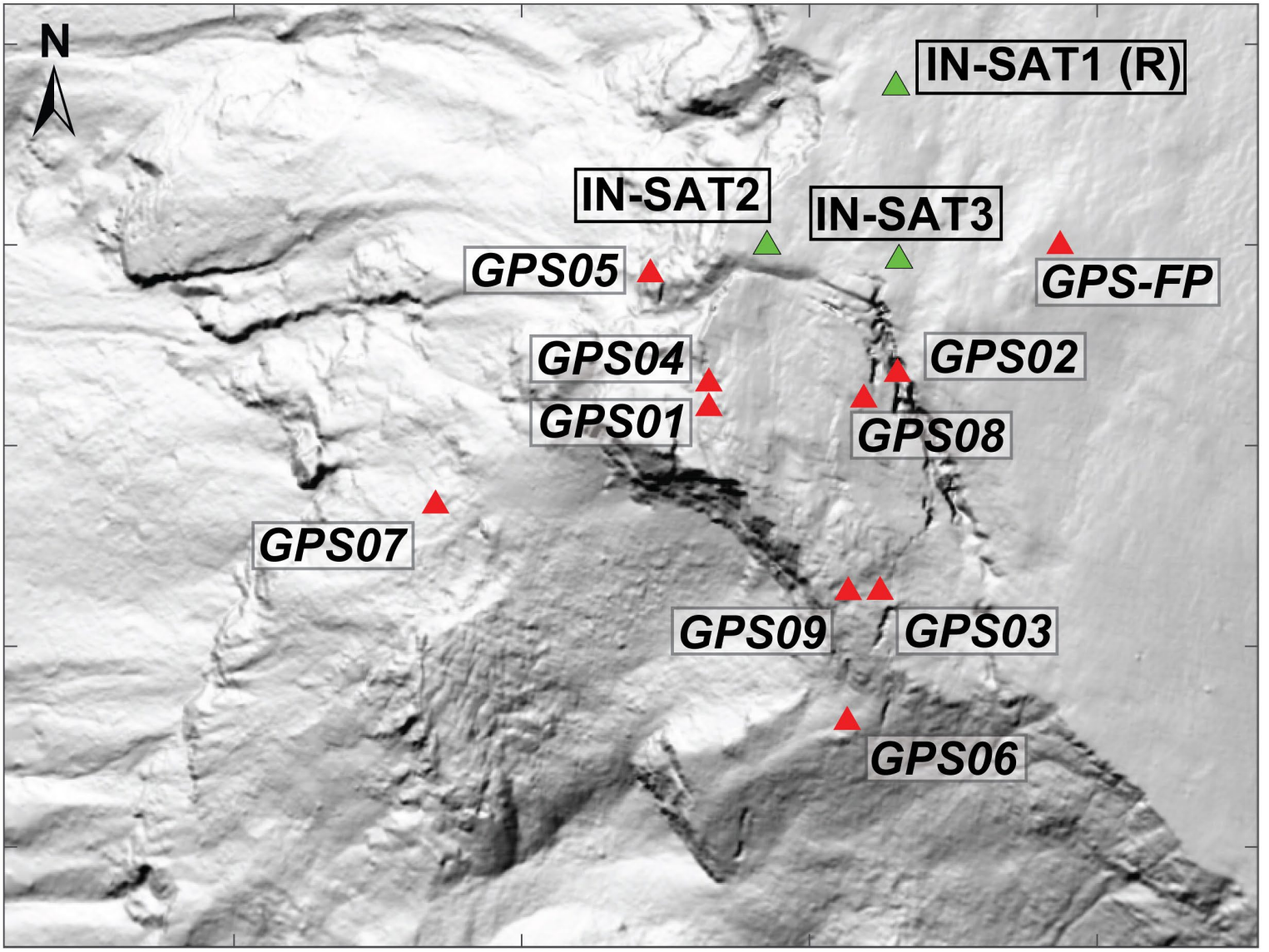
Gamanjunni

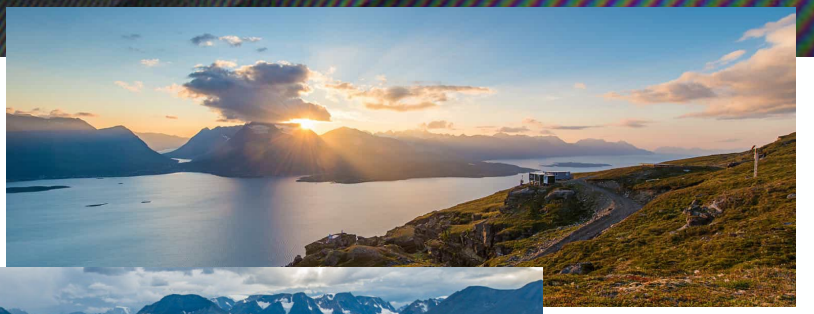
Gamanjunni

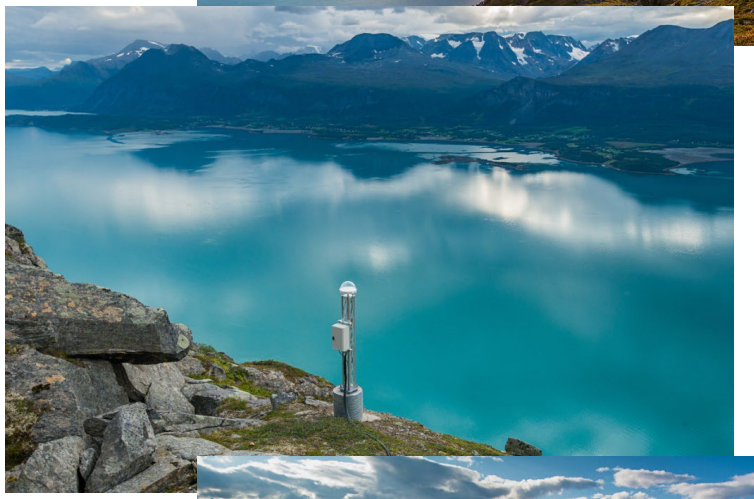


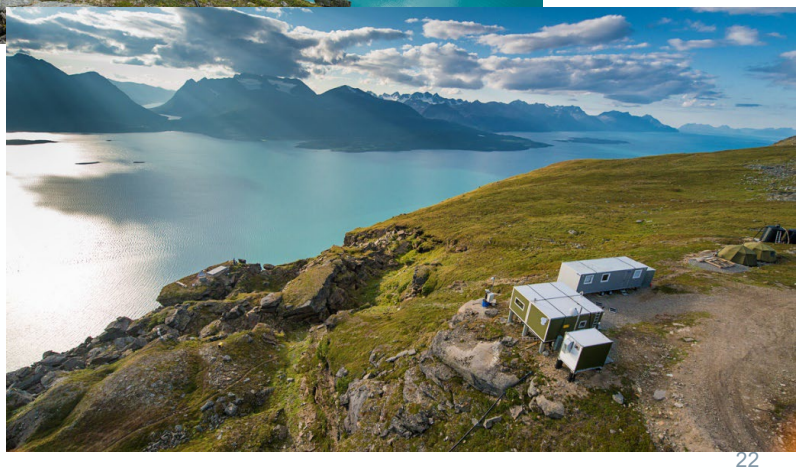


Indre Nordnes

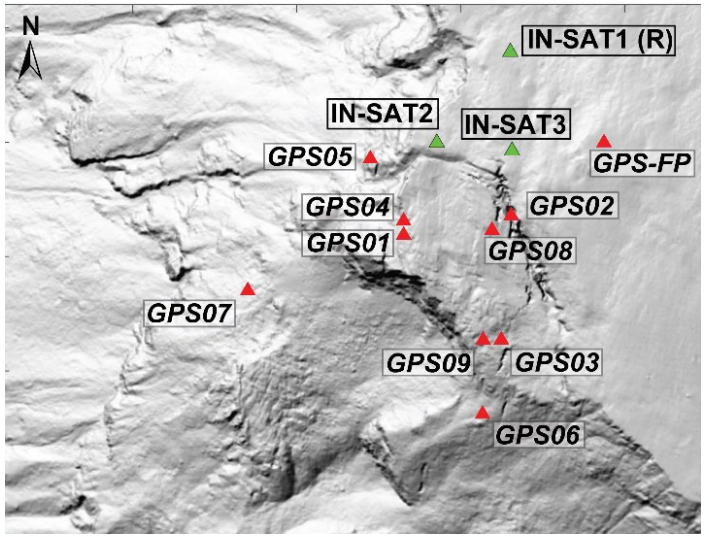


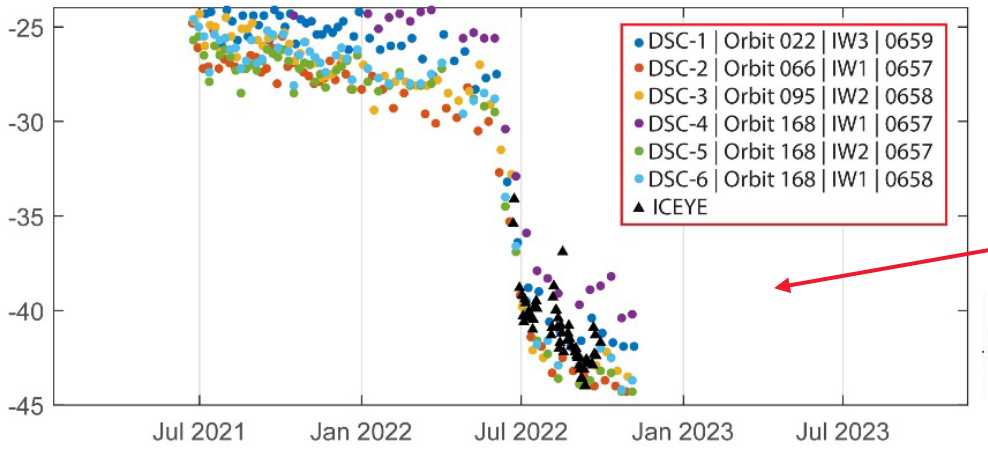


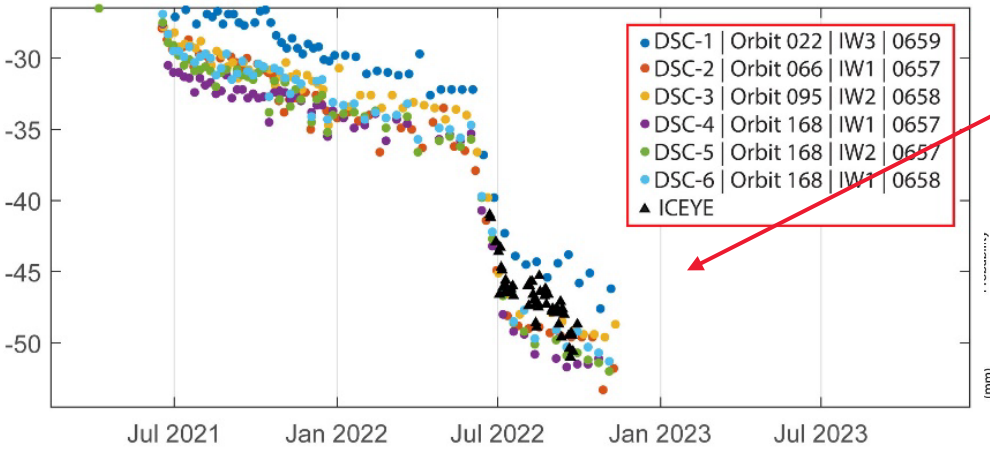


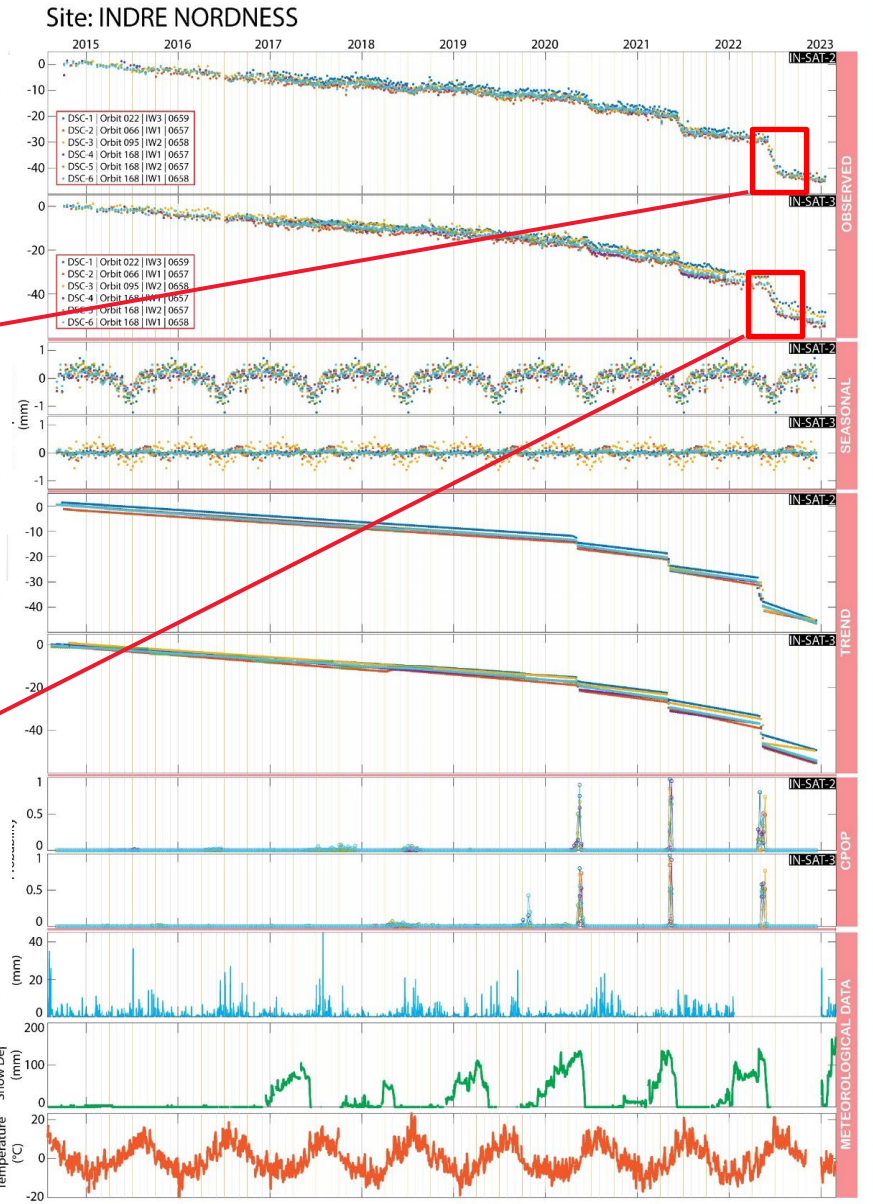


Indre Nordnes





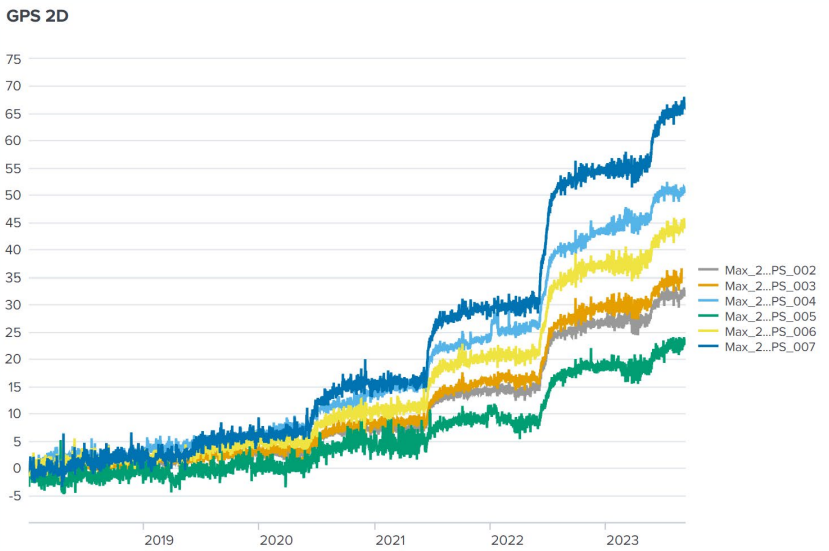


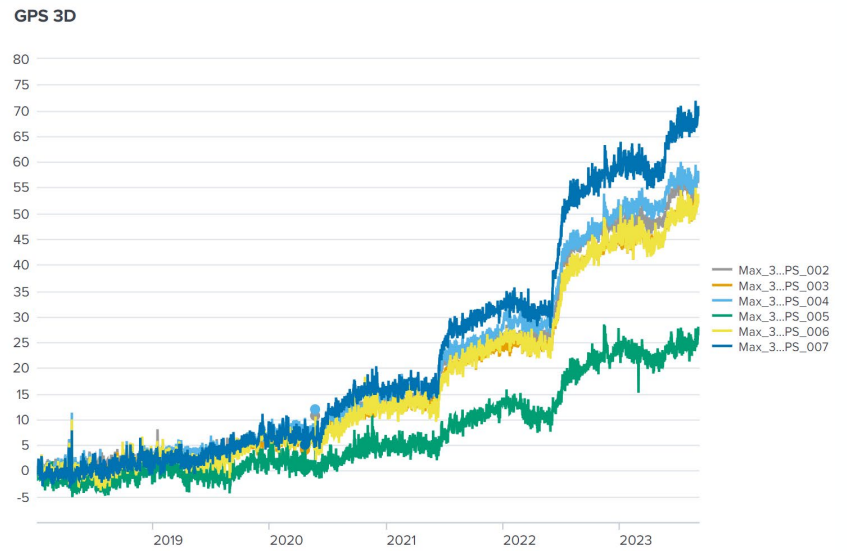


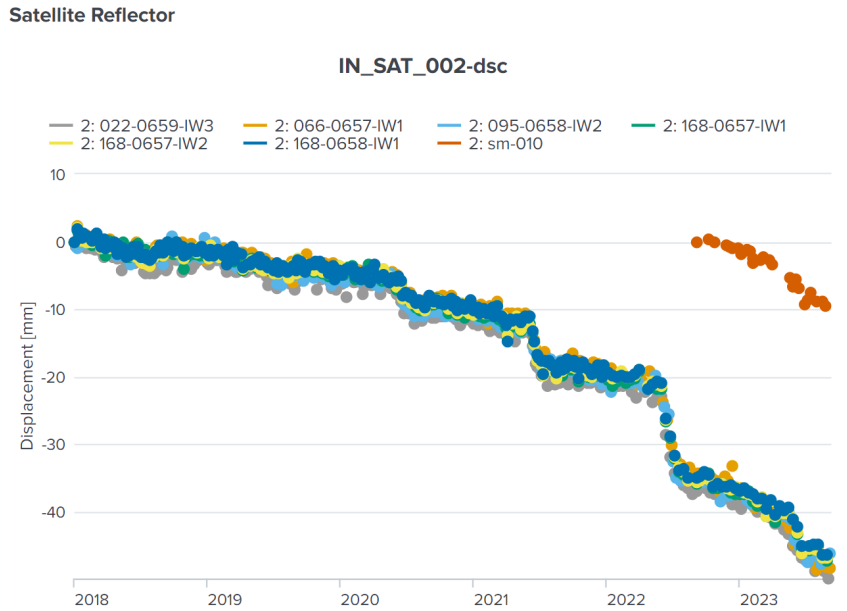
Indre Nordnes

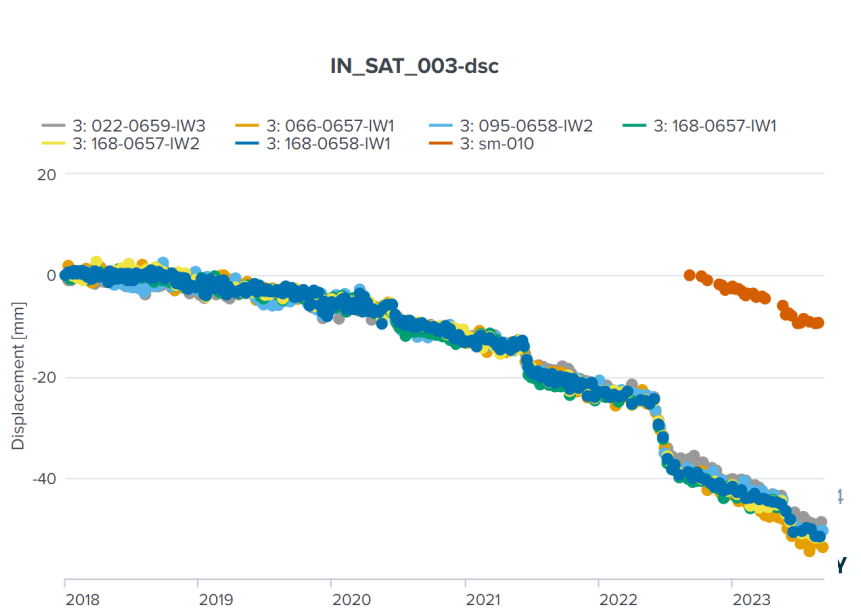
Seasonal acceleration in 2023 was not as high as 2022.

This, and several other sites, are being supplemented with COSMO-SkyMed to provide redundancy.









Adjet – rock glaciers

Geophysical Research Letters

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Key Points:

- Sixty-two years (1954–2016) of aerial photography and radar data document recent acceleration of a rock glacier complex in northern Norway
- Results show spatial and temporal variations as extension and compression, uplift, and subsidence in a permafrost landform
- Simultaneous increase of temperature and precipitation suggests that the landform is affected by permafrost warming

Recent Acceleration of a Rock Glacier Complex, Ádjet, Norway, Documented by 62 Years of Remote Sensing Observations

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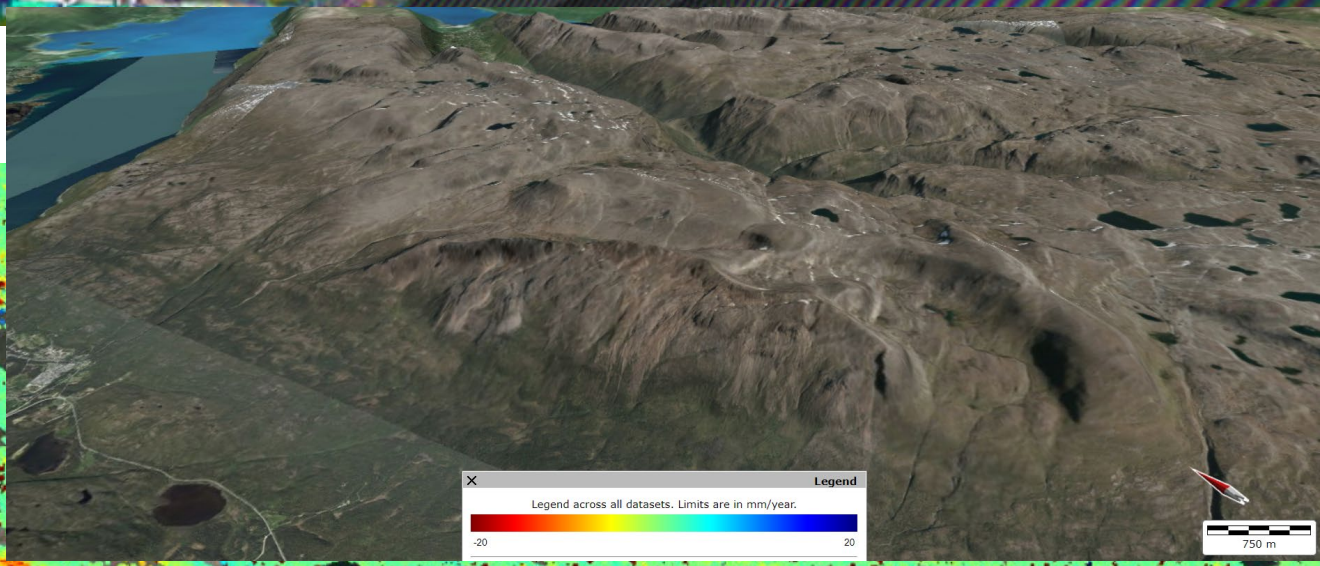
Abstract Recent acceleration of rock glaciers is well recognized in the European Alps, but similar behavior is hardly documented elsewhere. Also, the controlling factors are not fully understood. Here we provide evidence for acceleration of a rock glacier complex in northern Norway, from 62 years of remote sensing data.



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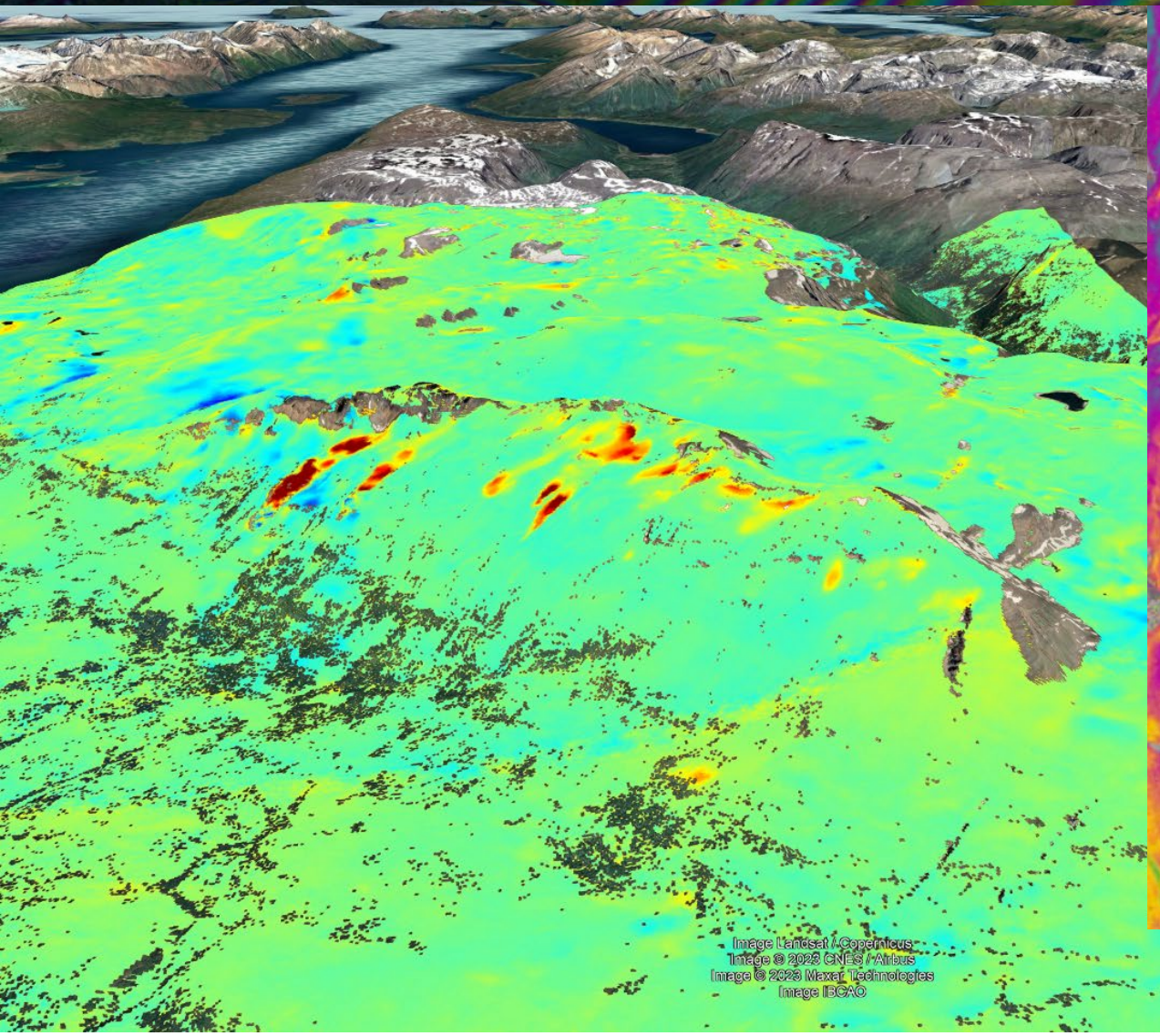

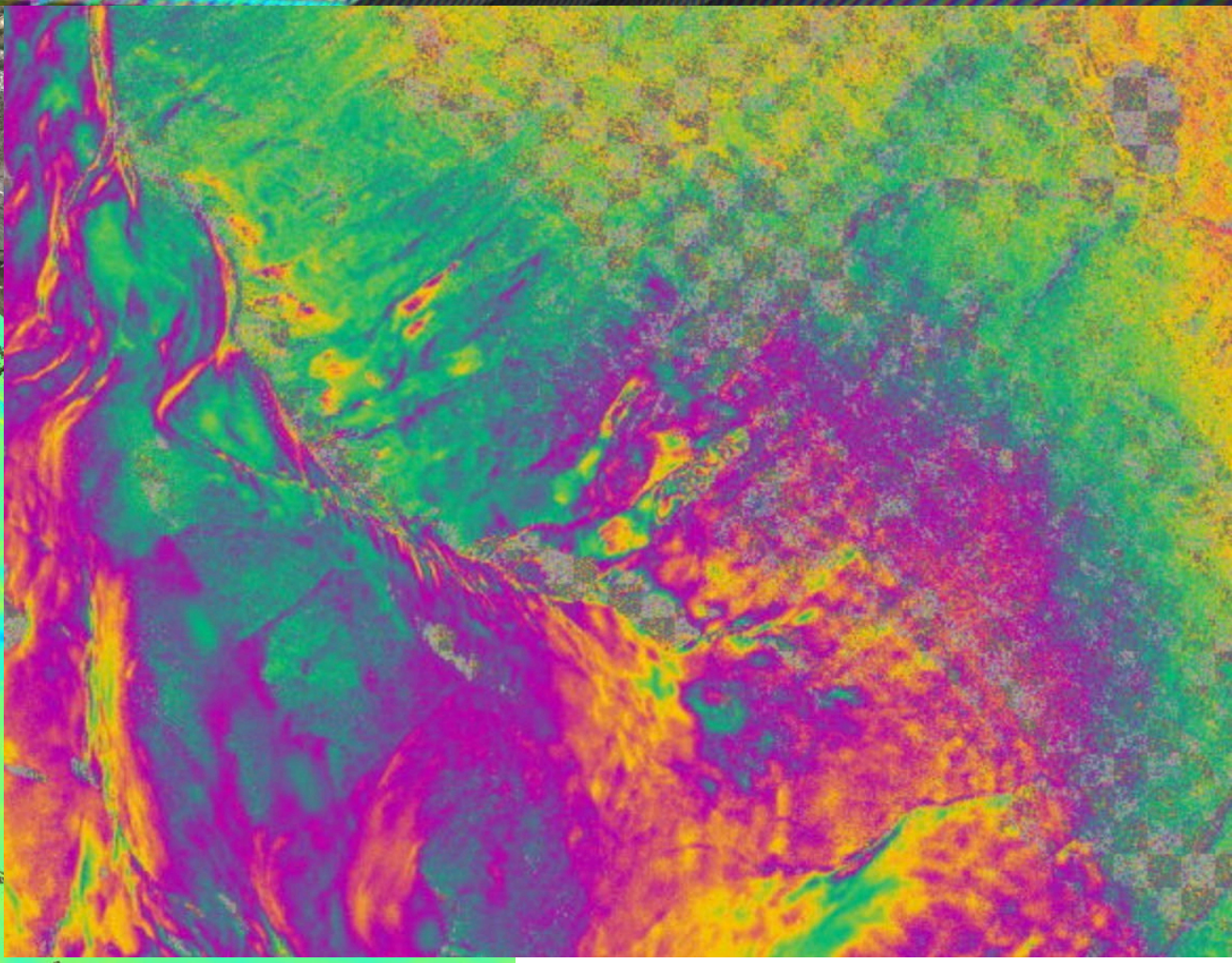

Conclusions

- Iceye “Daily Coherent Ground Track Repeat” product provided near-daily CR displacement measurements with similar quality to Sentinel-1.
- The large drifting baselines are not a problem for CR processing.
- For operational PS/DS InSAR, baselines <500m preferred/necessary .
- Orbital information needs to be better for operational use.
- Daily repeat coverage allows resolution of movement velocities up metres/year.
- Currently limited availability. In the future, this will change.