ICEYE DInSAR and InSAR time series for ground displacement mapping

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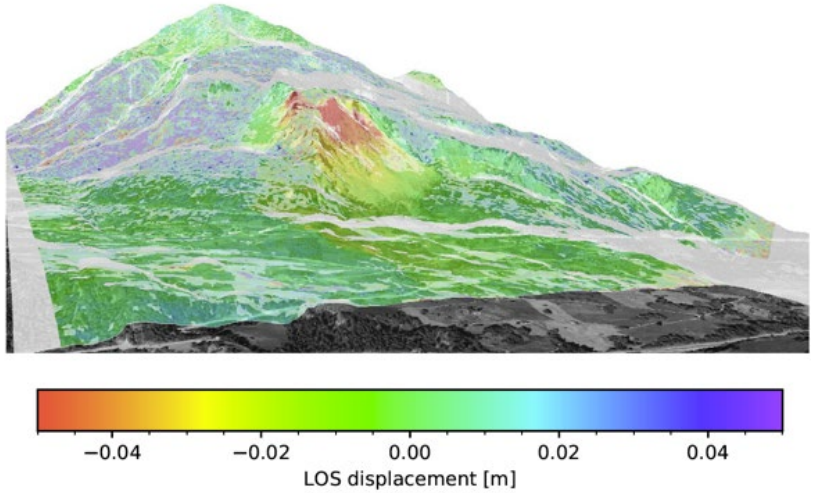
Background

- Work performed within the EUROSTARS Project *RAMON*
- The objectives was to develop landslide services considering innovative elements such as
  - terrestrial radar measurements (see below)
  - novel satellite SAR data (ICEYE)



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Share our ICEYE InSAR experience:

- DInSAR and SBAS test over Mojave, USA
- PSI test over Ichinomiya, Japan
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- Conclusions and recommendations

Initial DInSAR tests

2018/1	X1 ICEYE satellite
2018/12	X2 ICEYE satellite
2019/7	Two more satellites
2021/1	Three more satellites (incl. X6)
2021/7	Four more satellites

…

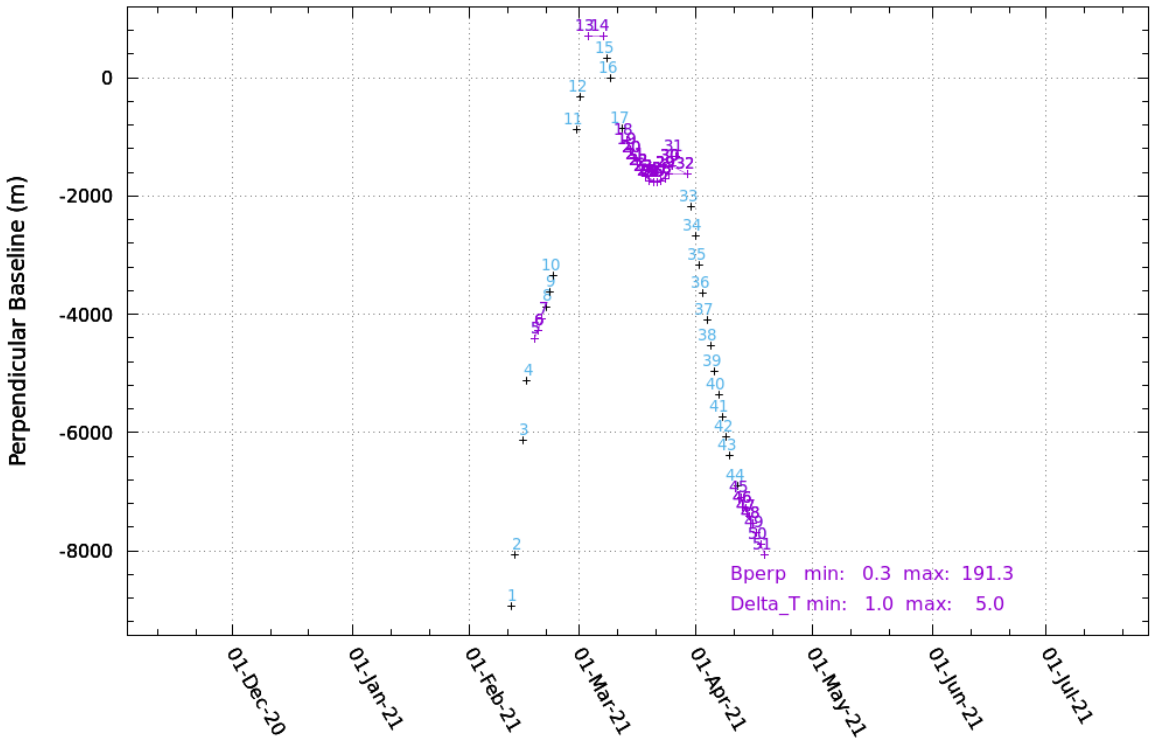
1) Before 2021 (X6-launch) the spatial baselines of repeat-observations have been too long for DInSAR (no strict orbit control to keep satellites in a narrow orbital tube)
2) From 2021 X6, operated in a one-day repeat-orbit provided suited interferometric pairs.
3) Drift (of X6) is about 200m per day.

DInSAR & SBAS test over Mojave, USA

- Data characteristics
- Coherence
- Phase
- Height information
- Displacement information

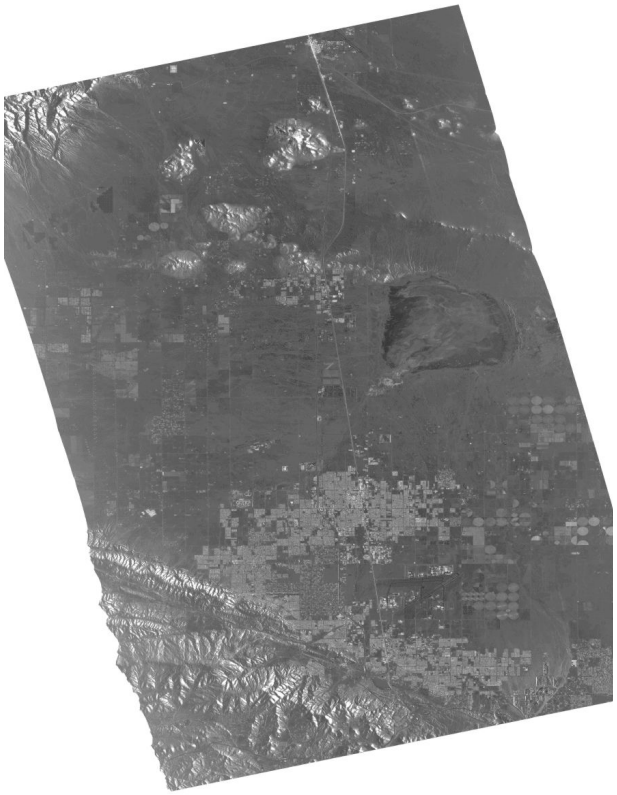
Data characteristics

- 51 stripmap mode X6 scenes (12-Feb to 19-Apr-2021)
- range / azimuth pixel_spacing: 0.92m / 1.43m
- Baselines: drifting, but short over short interval

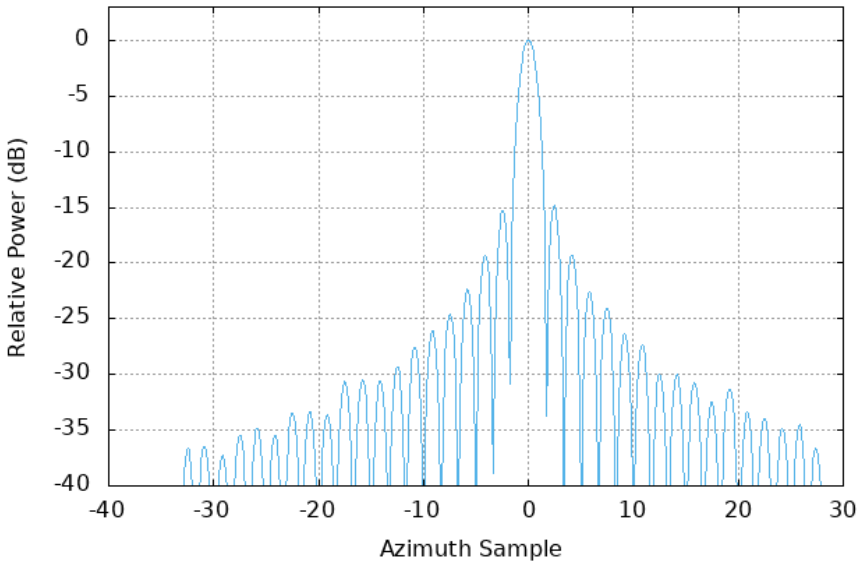


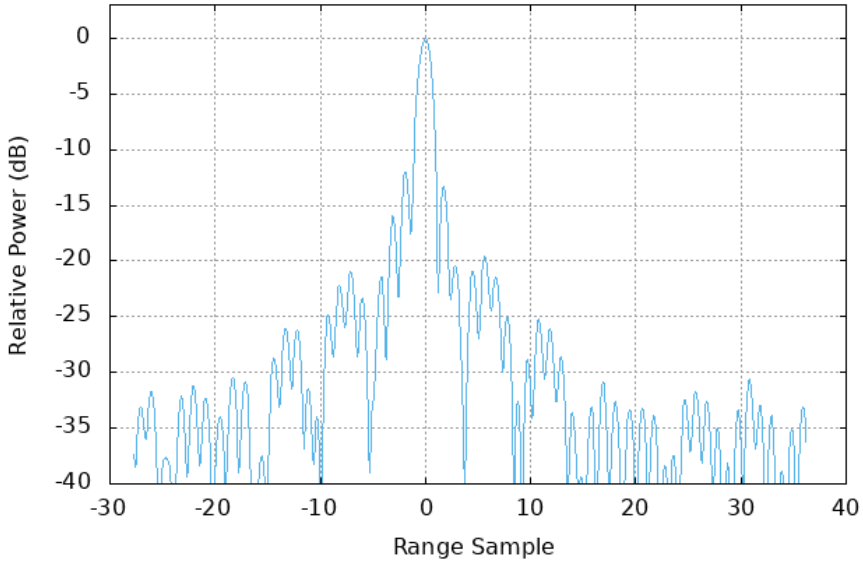
Backscatter and coherence

Average backscatter, small section shows corner reflector range



Backscatter and coherence





Azimuth and range pattern of a corner reflector (determined in average image over 51 scenes).
The Peak to Sidelobe Ratio is about 15 dB in azimuth and about 12 dB in range. The 3dB peak width is 1.1 azimuth sample and 1.5 range sample.

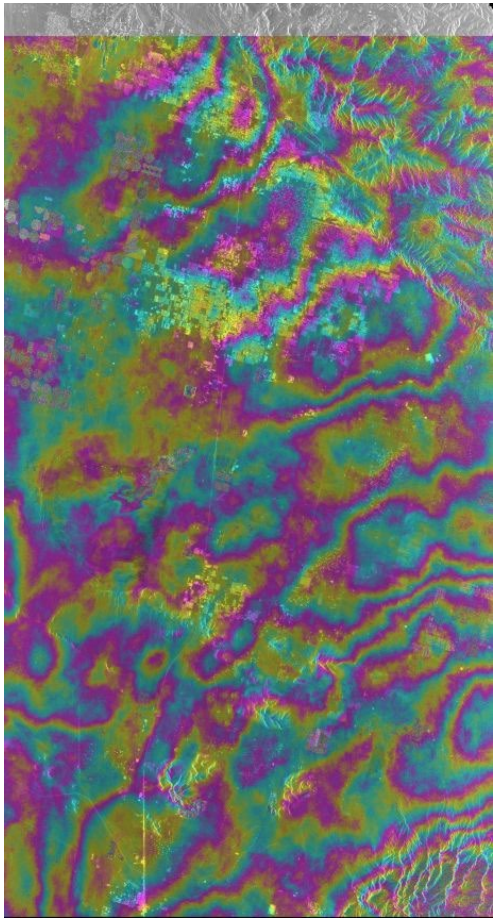
Backscatter and coherence

Average coherence (1-3 days intervals, $B_{\perp}$<200m)

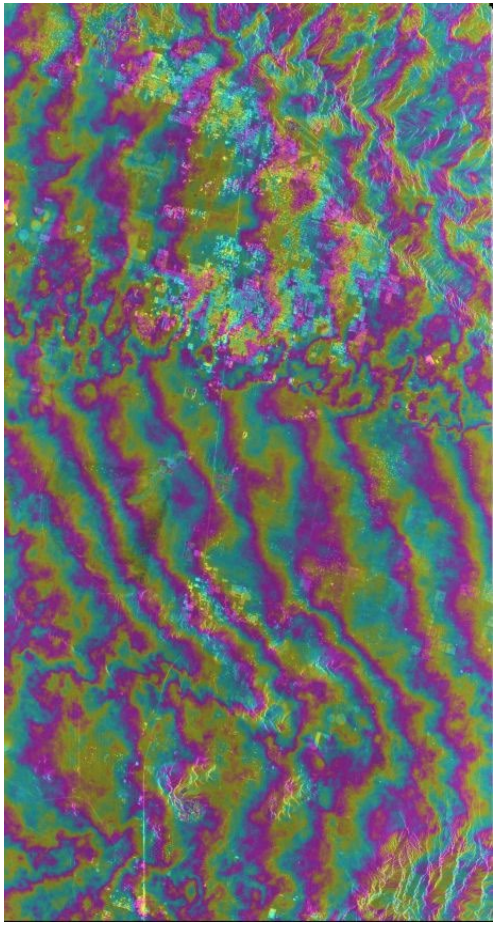
→

Reduced coherence by high NESZ, especially in near and far range.

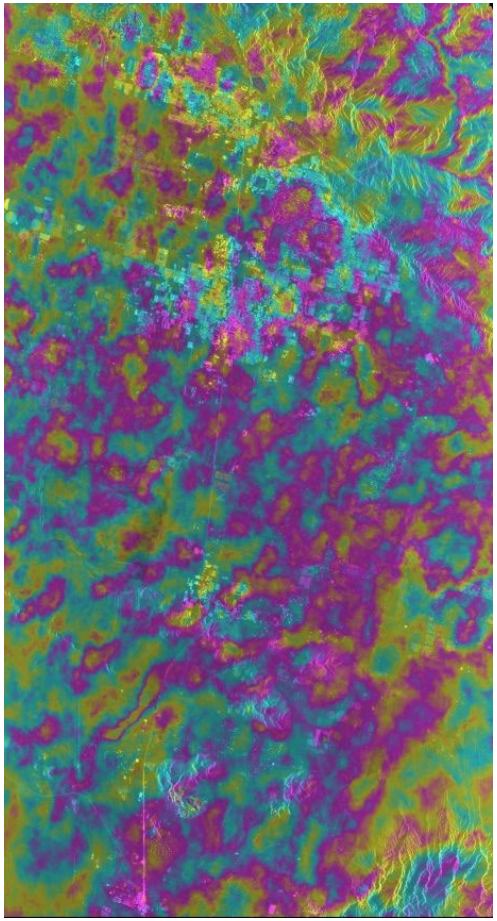
DInSAR phase



20210215_20210409,
dt=53d, $B_\perp$= 61m



20210308_20210309,
dt=1d, $B_\perp$=-358m



20210415_20210416,
dt=1d, $B_\perp$=-111m

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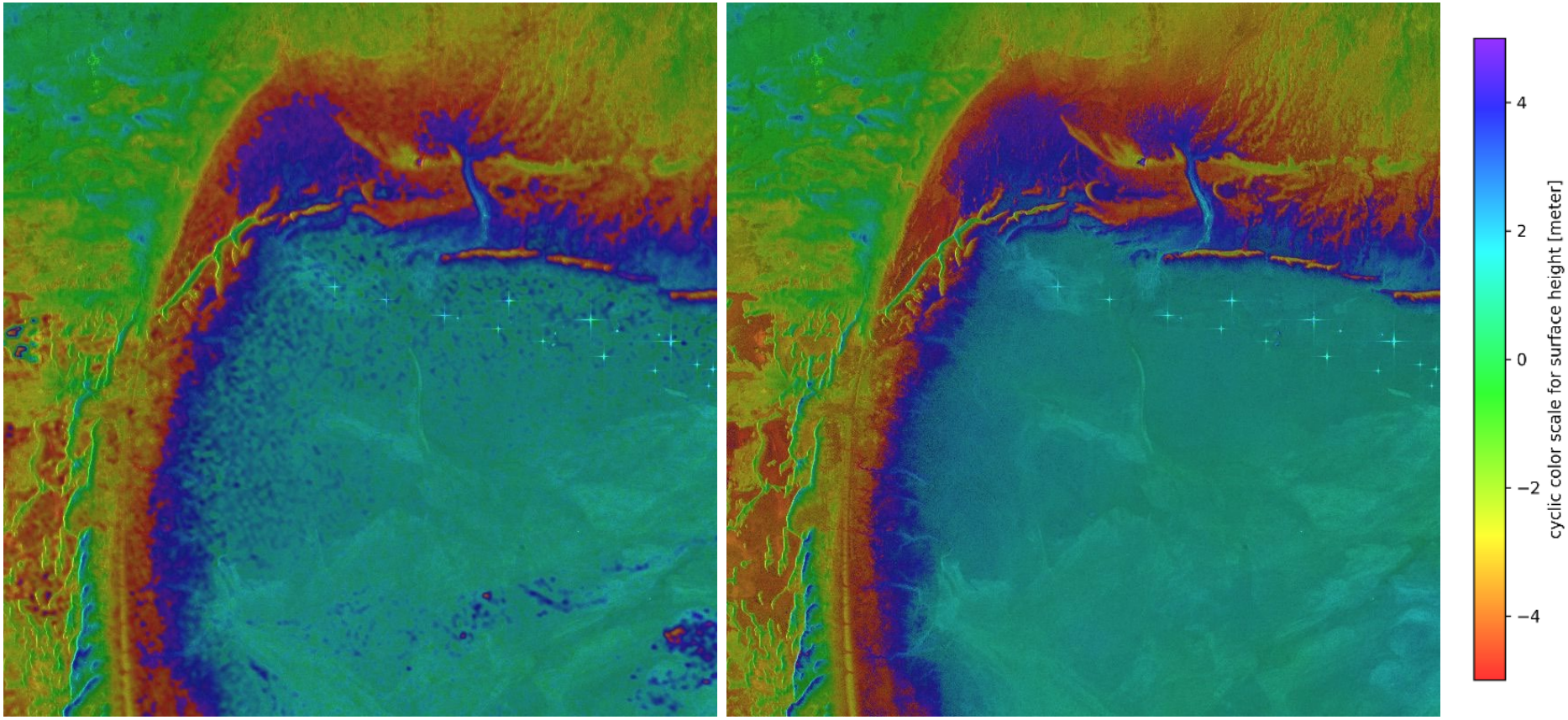
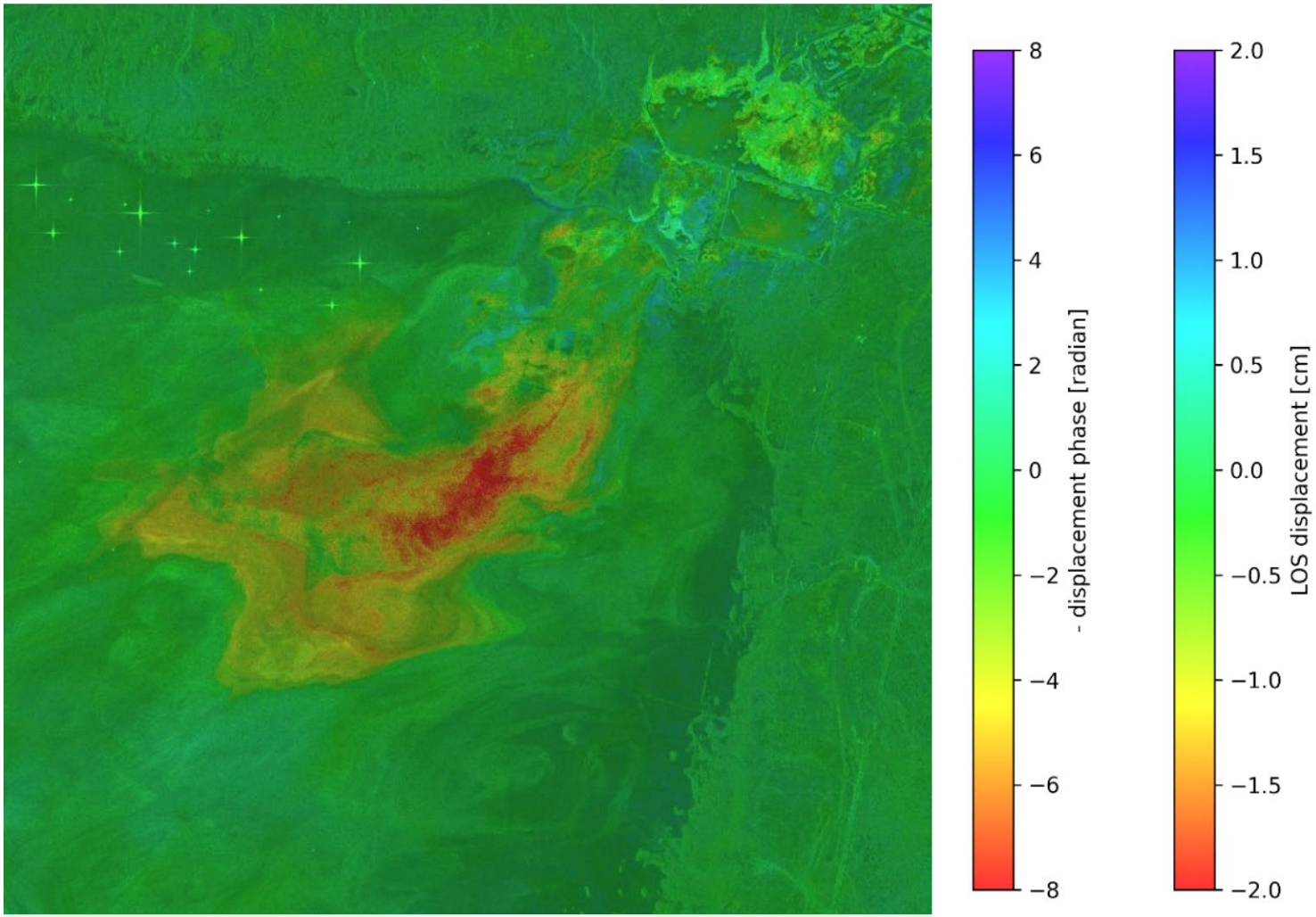
Examples of differential interferograms

Terrain height estimation



Oversampled Copernicus DEM height (left) and ICEYE based updated DEM (right) for a 5.6km x 5.6 km area, using a fine cyclic color scale.

Ground-displacement estimation (SBAS)



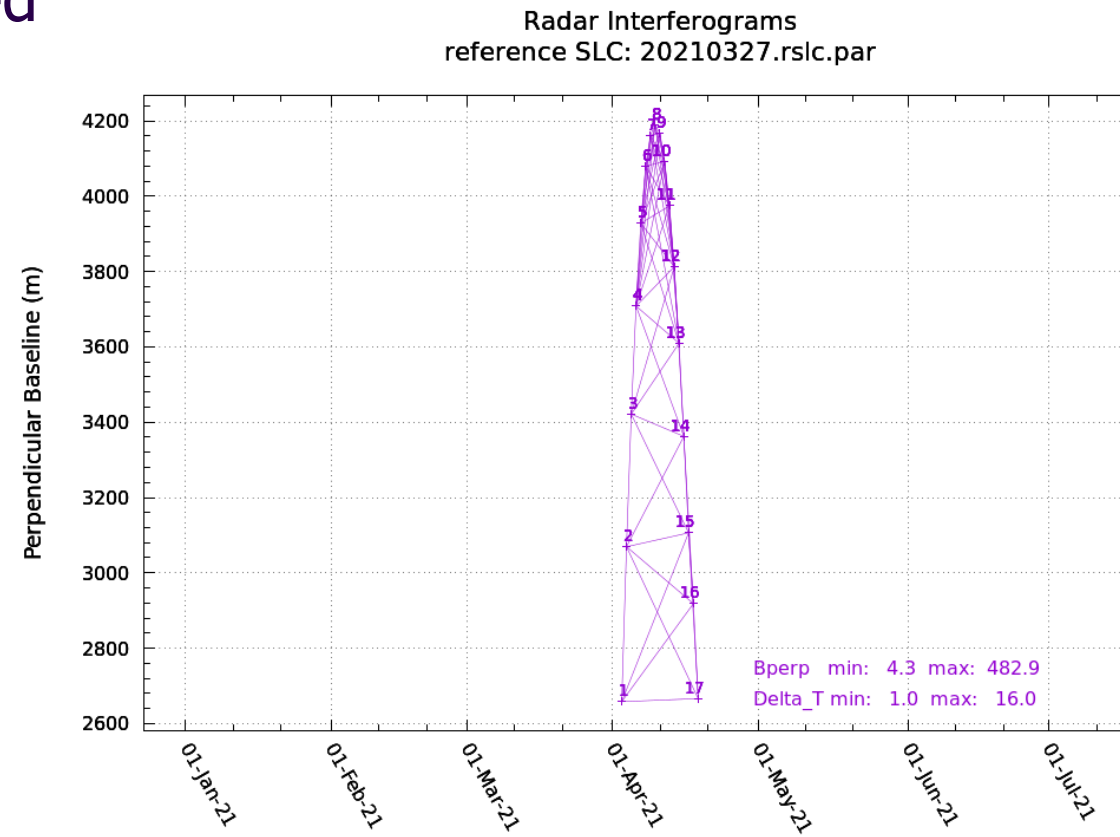
LOS displacement between 20210212 and 20210419 (67 days)

PSI test over Ichinomiya, Japan

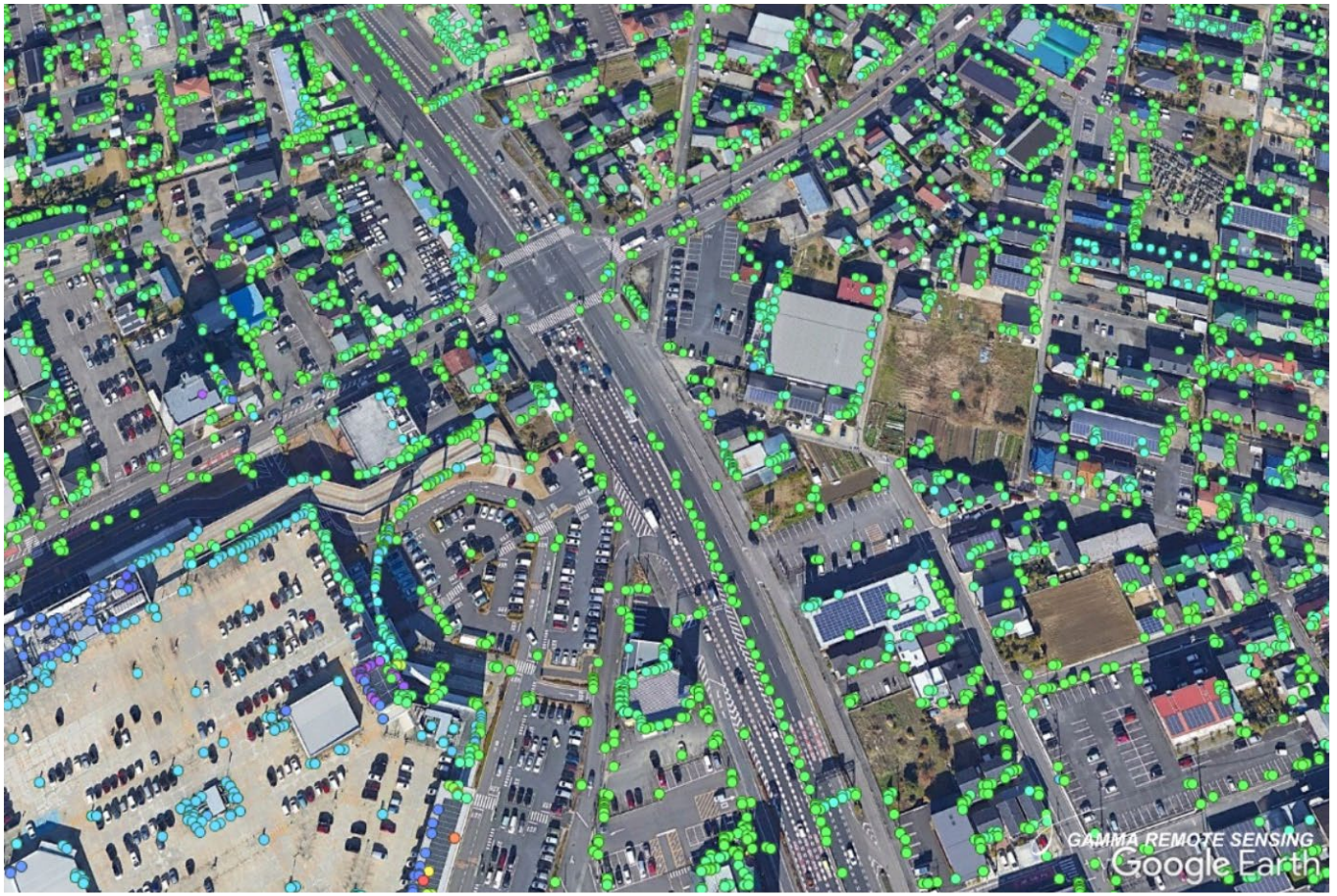
- Urban section in Tokyo area
- 37 X6 spotlight mode SLC, 17 used for PSI
- Single pixel phases used

Potential:

+ Point heights
+ Positions
- mm/year disp. rates



PSI heights visualized in Google Earth



Statistical height estimation error: ~ 0.15m

Positional accuracy confirms accuracy of estimated heights.

Coherence Product over Ichinomiya

RGB composite of average coherence, average backscatter and backscatter temporal variability of spotlight mode ICEYE X6 stack over Ichinomiya, Japan (1.8km x 1.3km).

SBAS test over Disko Island, Greenland

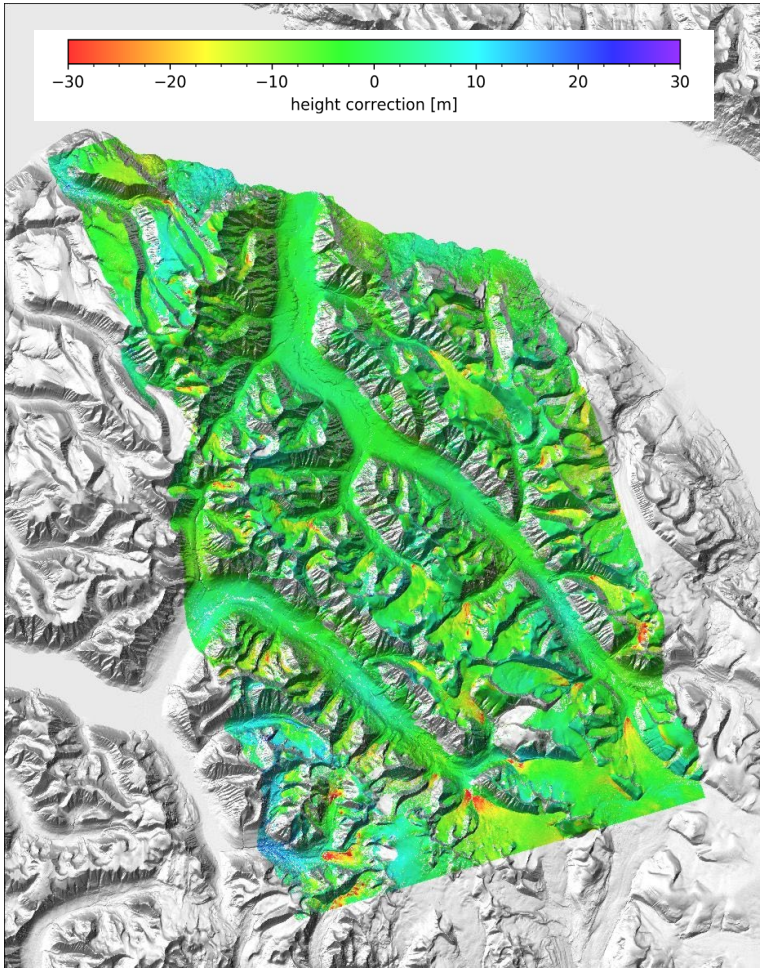
- Interest in X6 time series to map and monitor fast displacements in the Swiss Alps → no X6 coverage possible.
- Looking for an alternative site with fast displacements and we identified Disko Island, Greenland.

→ ICEYE X6 acquired an interferometric data stack with 1-day intervals.

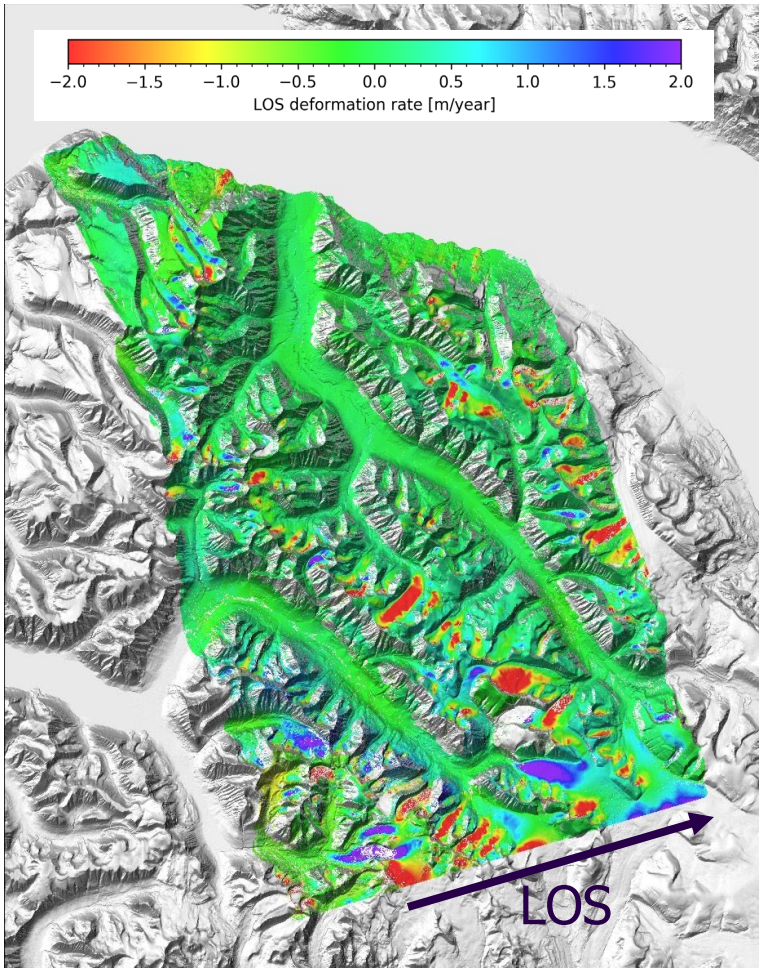
Expected potential:

+ Height differences relative to reference DEM
+ Position and rate of fast LOS displacements

ICEYE SBAS results over Disko Island (Dec. 2021)



Height correction



LOS displacement rate

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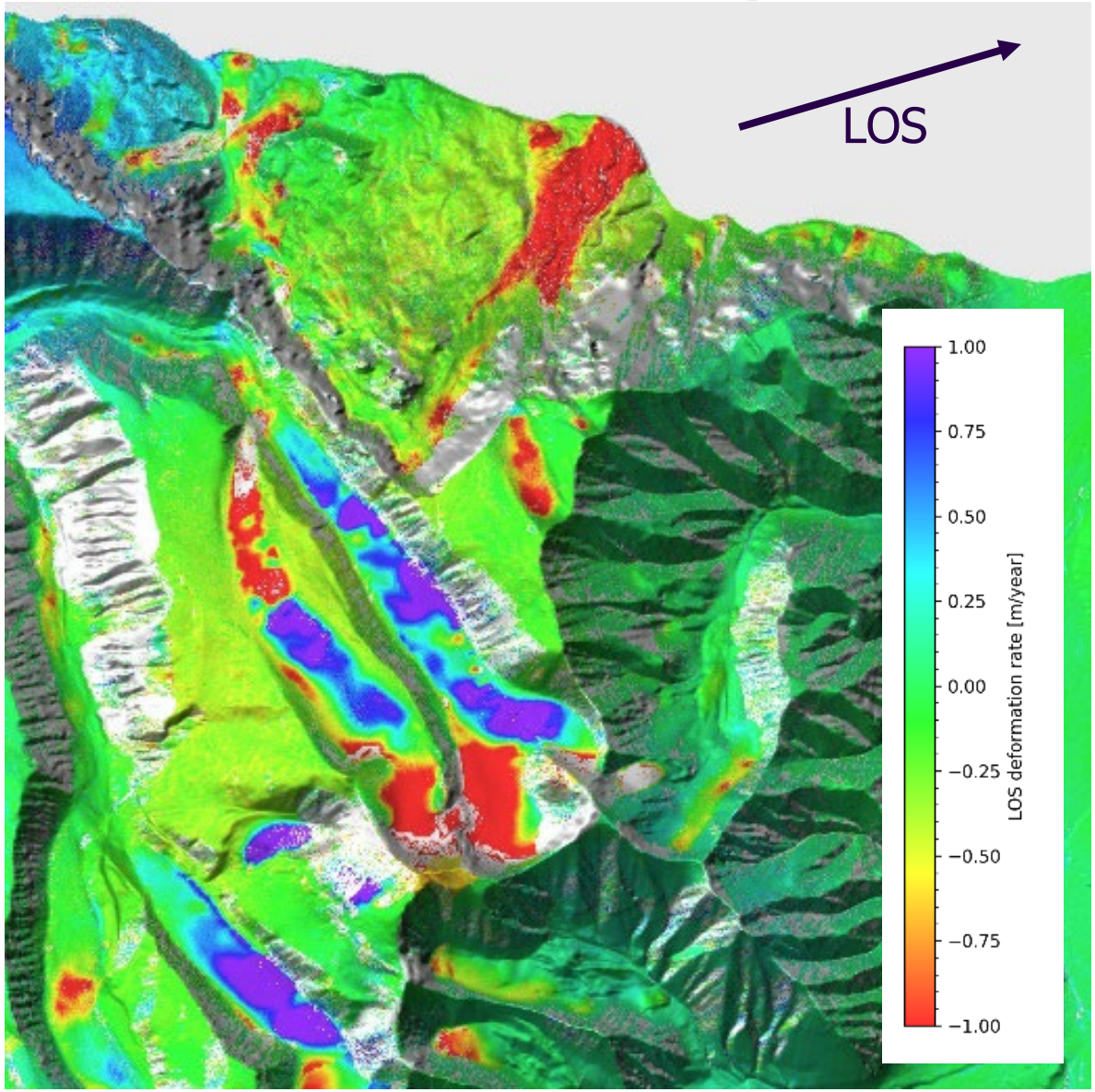
ICEYE SBAS results over Disko Island (Dec. 2021)

- Glaciers
- Rock glaciers
- Landslides



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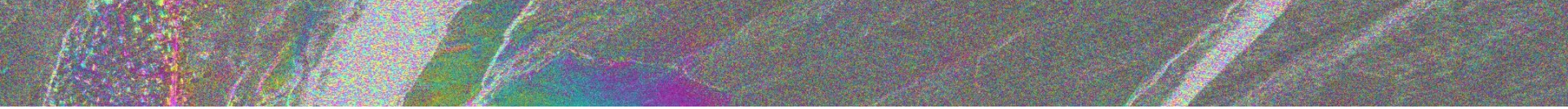
Conclusions

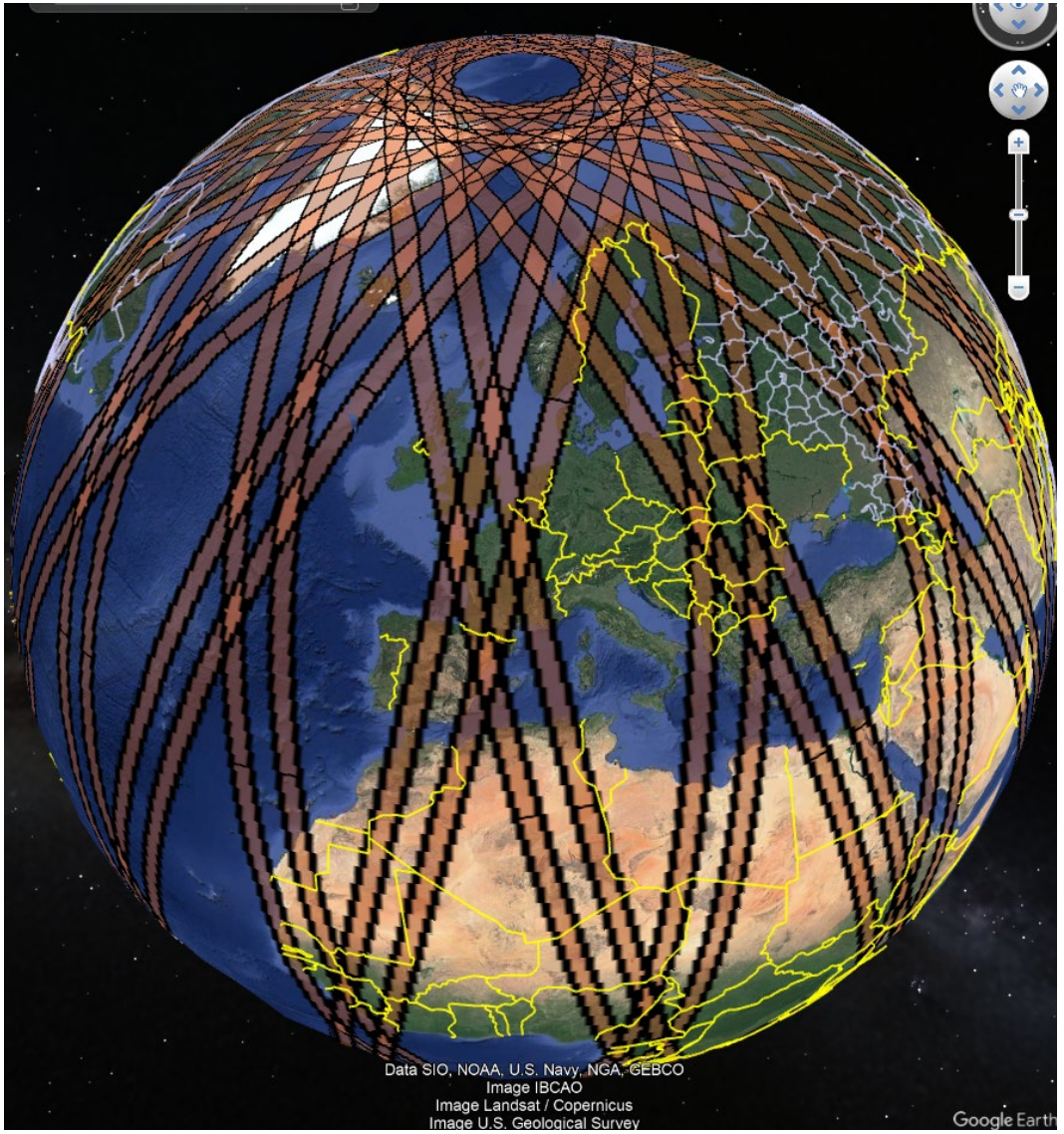
- ICEYE data are well suited for DInSAR, PSI, SBAS, provided the spatial baselines are sufficiently small.
- High spatial resolution X-band time series with short 1-day time intervals are particularly well suited for the mapping and monitoring of local mm to cm scale ground motion.
- Drifting orbits and narrow swaths limit the applicability.
- High NESZ values reduce the backscatter contrast and the coherence.

Recommendations

- Operating the ICEYE satellites in narrow orbital tubes (< 500m) would strongly improve the InSAR applicability.
- Using higher gain antennas or increasing transmitter power would reduce the NESZ – resulting in higher quality backscatter images and higher coherence.



ICEYE X6 (potential) coverage



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Offset tracking test over Mojave, USA

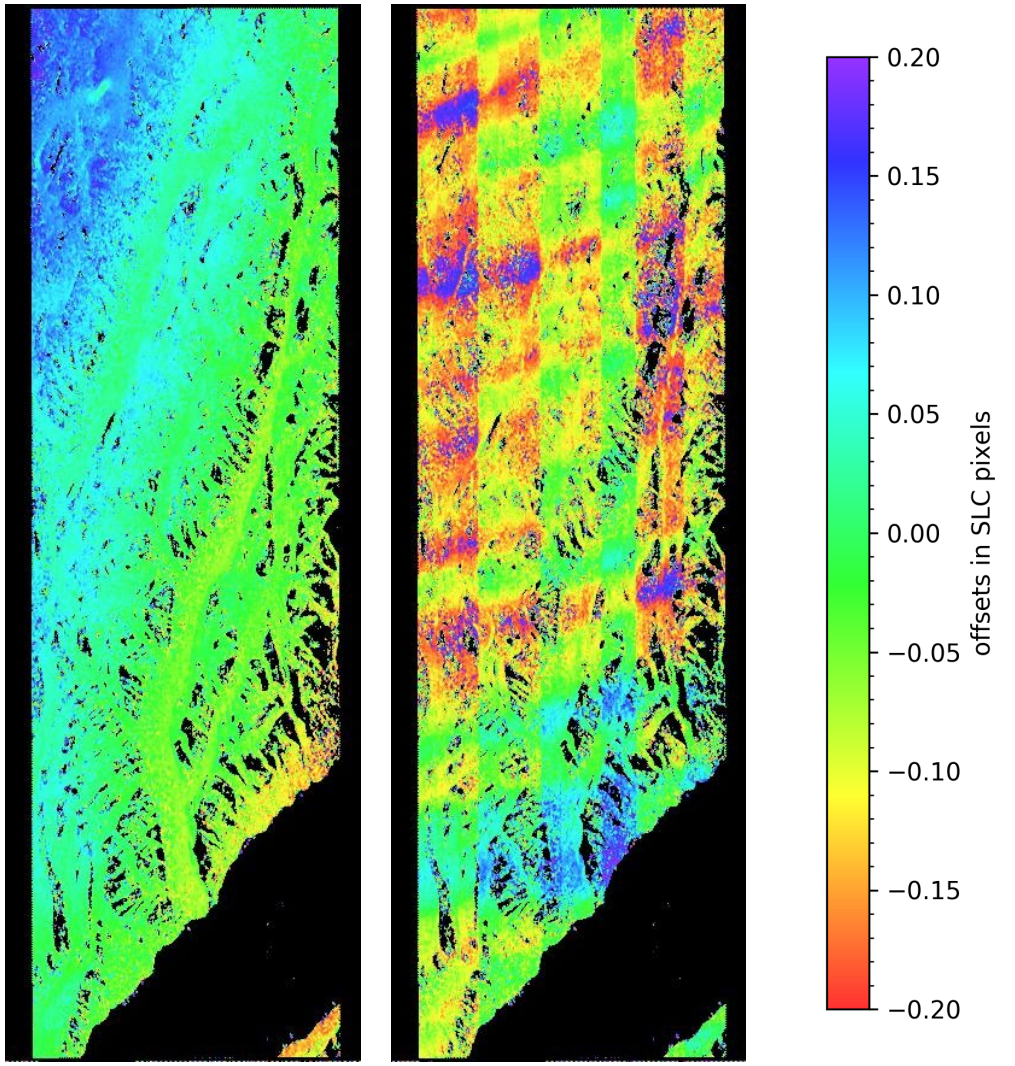
Stripmap mode

24-25 Dec. 2021

Dt 1 day

$B_{\perp}$ 16m

Processing issues ?



range offsets azimuth offsets

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