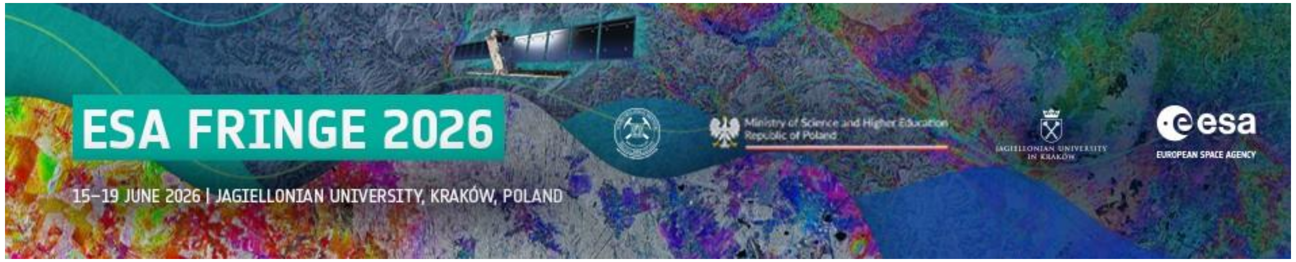


Session: Future SAR missions and concepts 2
Wed, June 17, 2026 : 12:30-12:50

Monostatic and bistatic SAR imaging and SAR interferometry with UAV-borne and car-borne SAR systems at L-band and S-band: results from our latest campaigns

Othmar Frey [1,2], Charles Werner [1], Rafael Caduff [1], Tazio Strozzi [1], Silvan Leinss [1], Tobias Batt [1]

[1] Gamma Remote Sensing, Switzerland, [2] ETH Zurich, Switzerland

Elias Deeb [3], Adam LeWinter [3], Dominic L. Filiano [3],

Cameron J. Wagner [3], David C. Finnegan [3]

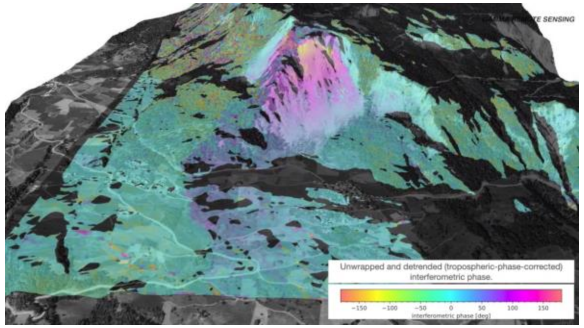
[3] US Army Cold Regions Research and Engineering Laboratory (CRREL), USA

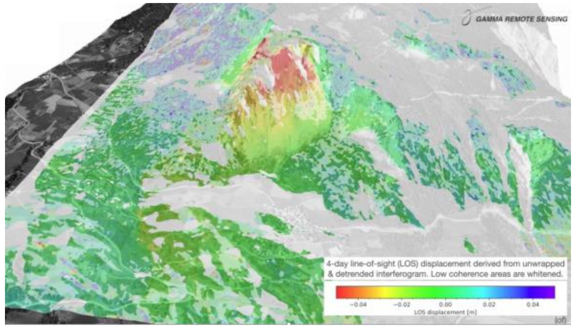
Tim Dixon [4], Taha Sadeghi Chorsi [4]

[4] University of South Florida, USA

GAMMA REMOTE SENSING

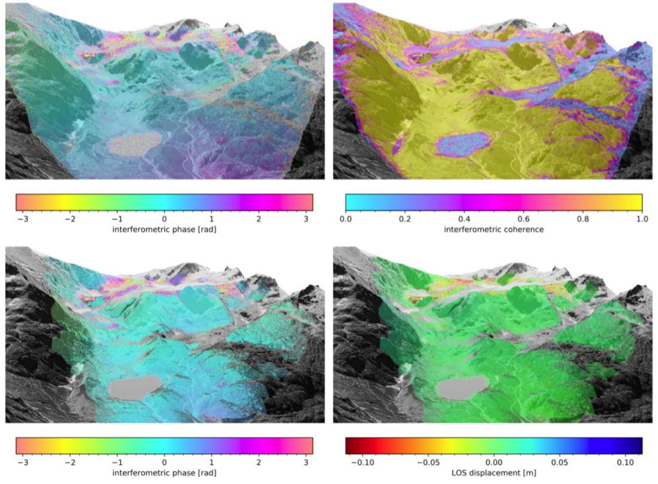
First demonstrations of **UAV-borne DInSAR at L-band** and **car-borne DInSAR at L-/S-/Ku-band using Gamma SAR systems**

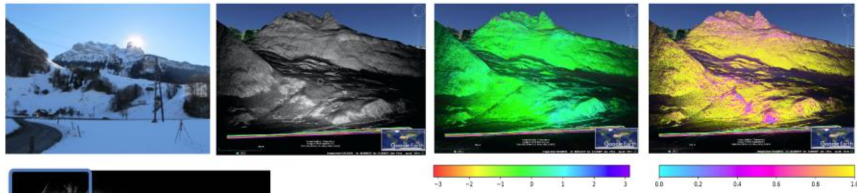


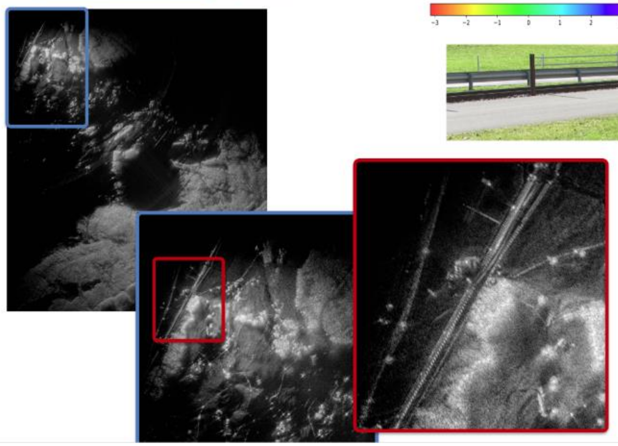


2020

2018







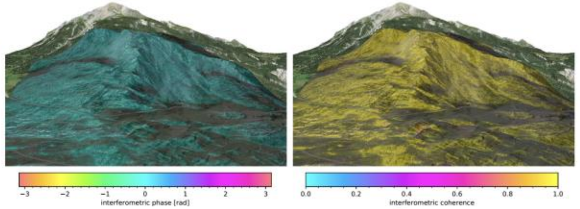
2019

2023

Short-term (2.5min, 2023-10-16) interferom. phase & coherence

Car-borne SAR

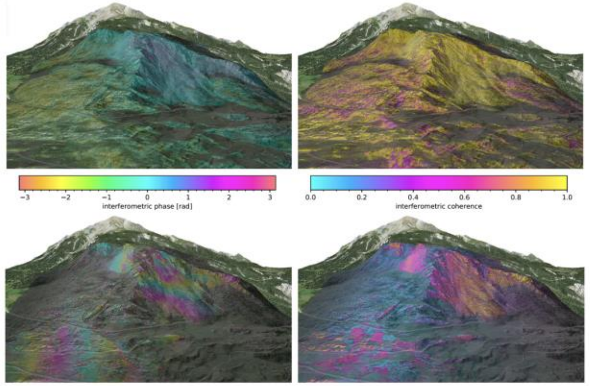
- L-band
- Ku-band



1-day (2023-10-16 to 17) interferometric phase & coherence

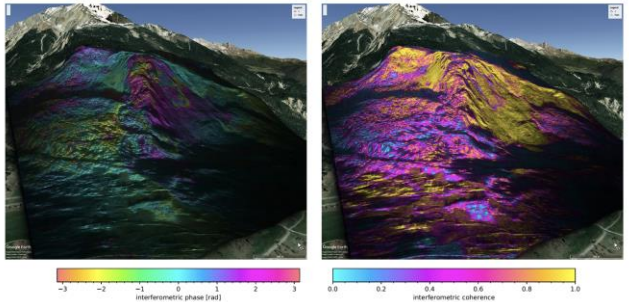
Car-borne SAR

- L-band
- Ku-band



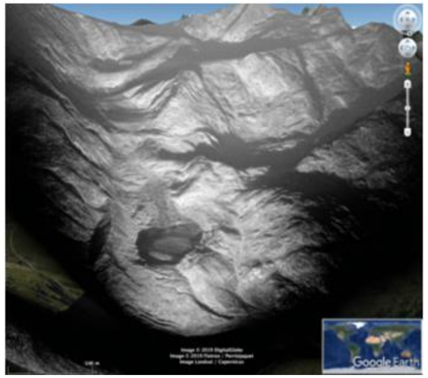
S-Band ~ 1d 16h : 20240820T164209_20240822T082704

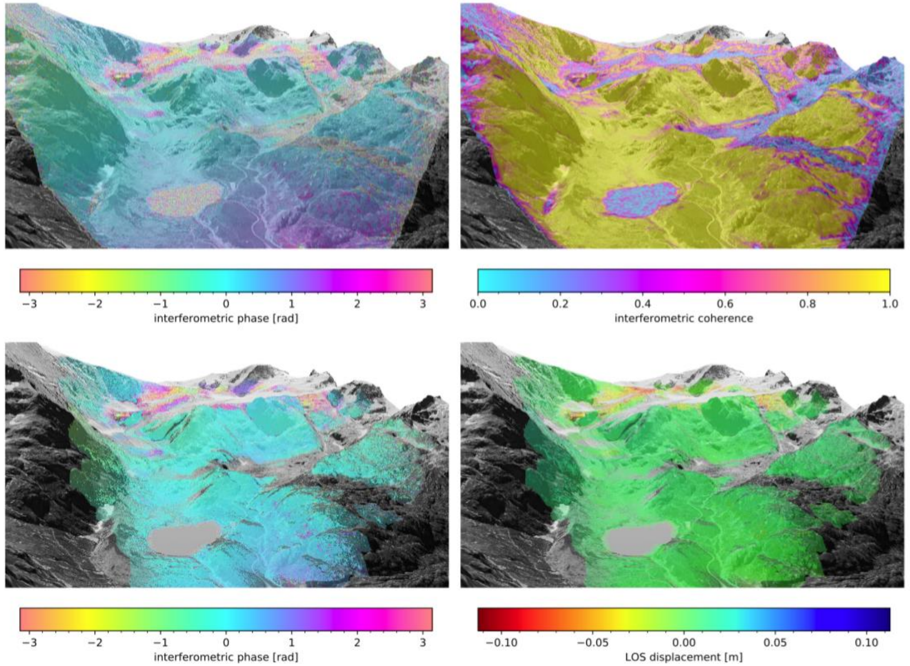
2024



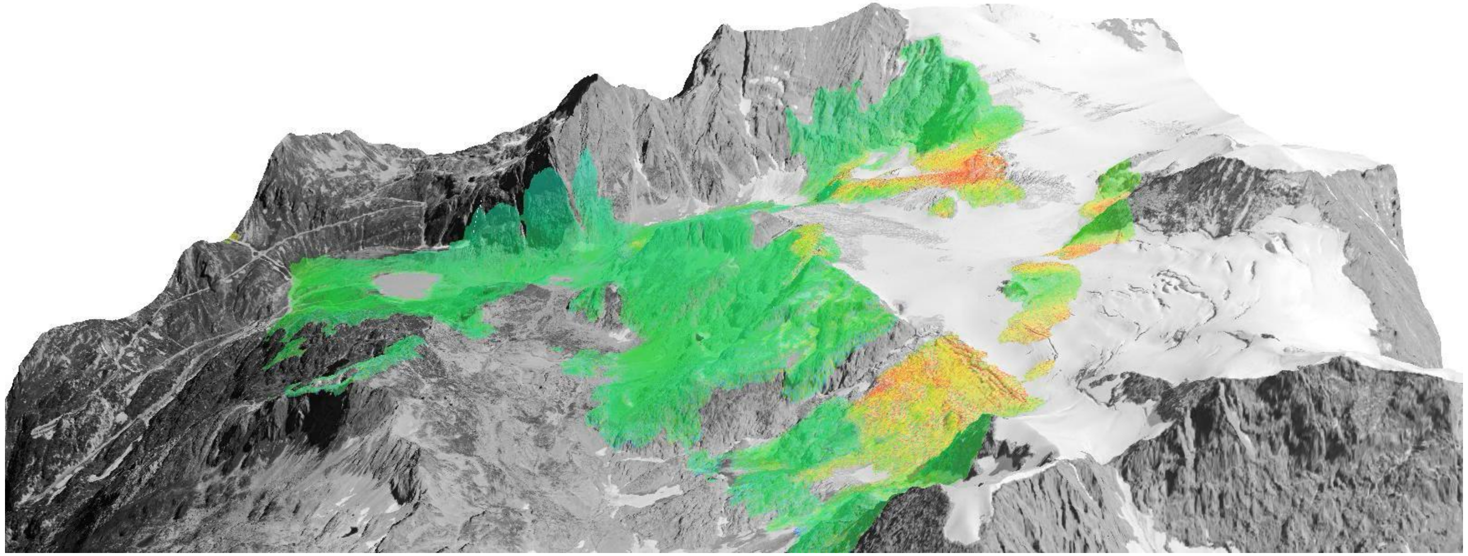
GAMMA REMOTE SENSING

First demonstrations of **UAV-borne DInSAR at L-band** and **car-borne DInSAR at L-/S-/Ku-band using Gamma SAR systems**





2018

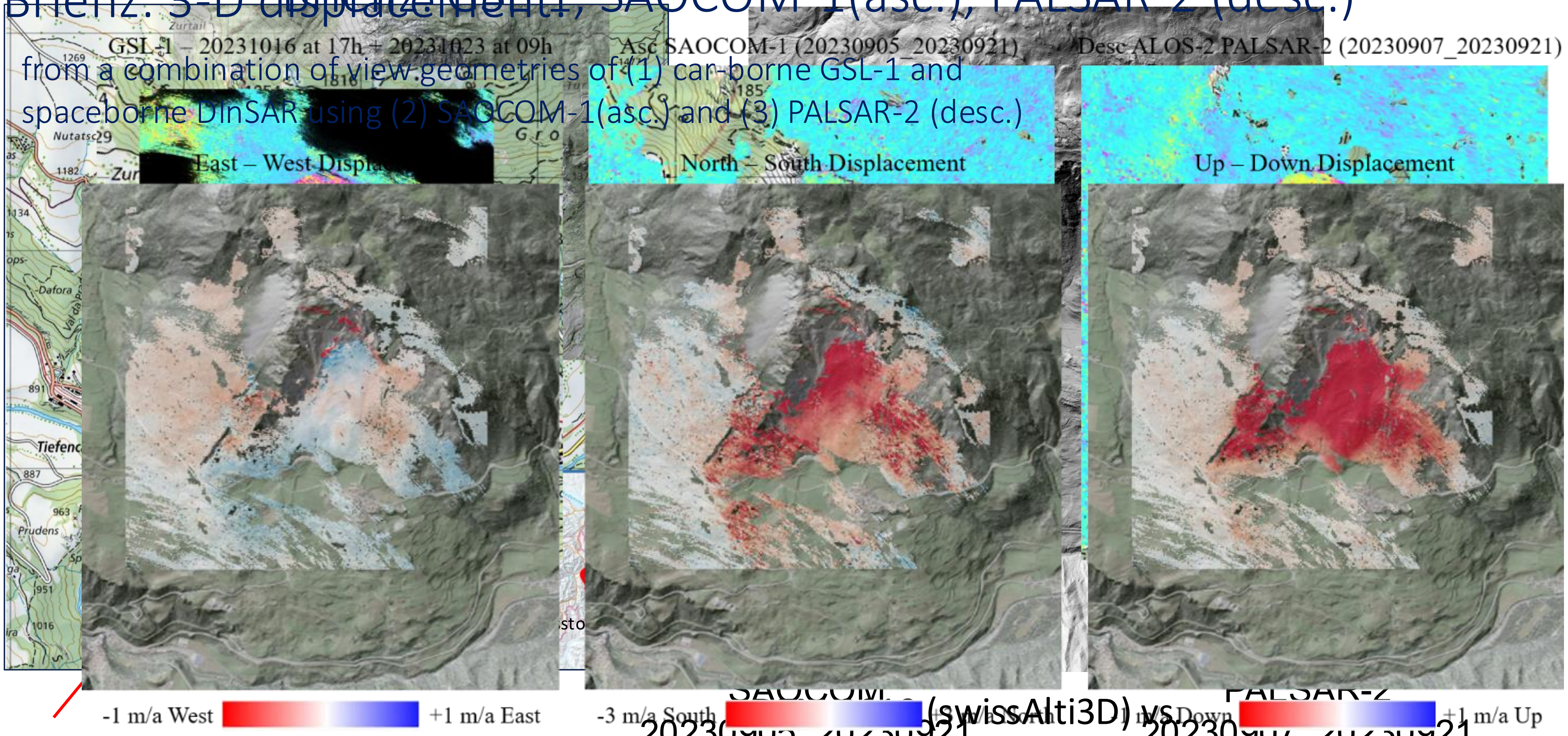


Landslide Brienz, Switzerland, GSL-1, 16.-23.10.2023

Brienz: 3-D displacement:

Brienz: GSL-1, SAOCOM-1(asc.), PALSAR-2 (desc.)

from a combination of view geometries of (1) car-borne GSL-1 and spaceborne DInSAR using (2) SAOCOM-1(asc.) and (3) PALSAR-2 (desc.)



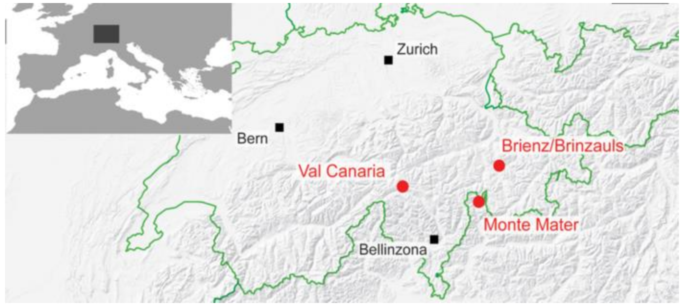
Road section used for L-band SAR measurement

SAOCOM-1
20230905_20230921
117.6 mm @ 1.275 GHz

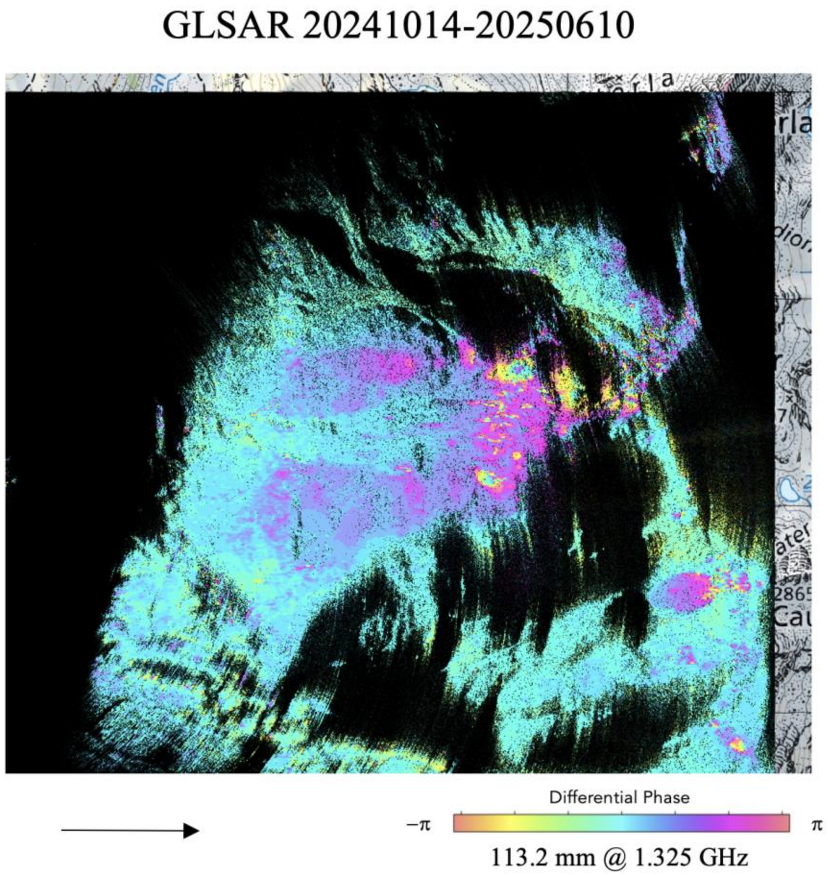
PALSAR-2
20230907_20230921
118.1 mm @ 1.270 GHz

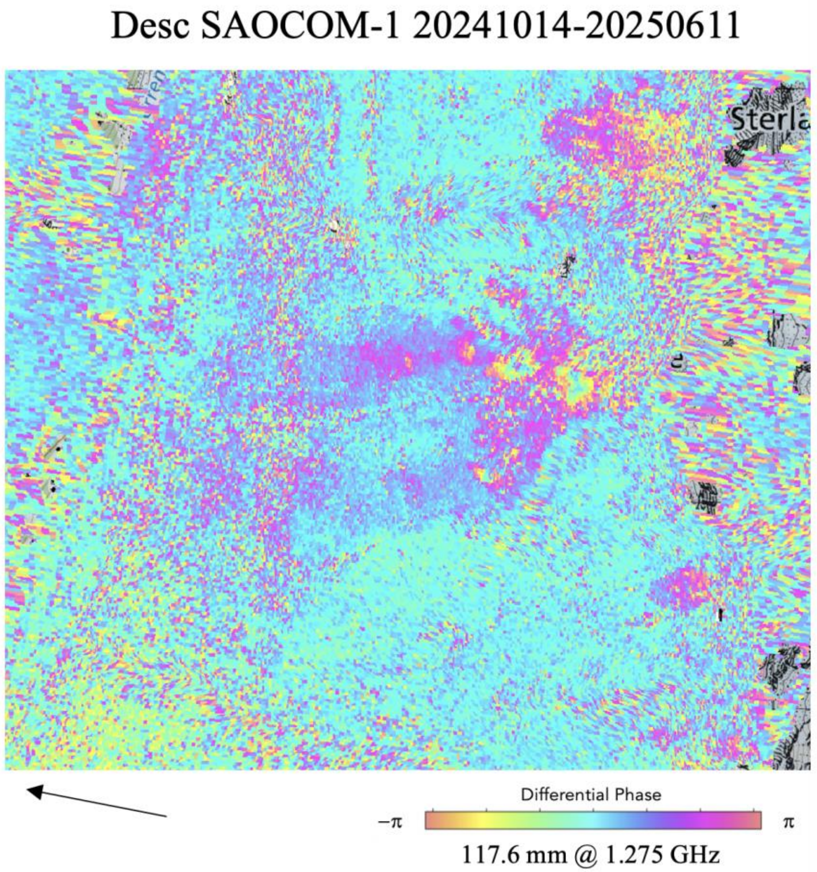
(swissAlti3D) vs DEM 2023-10-03 (Helimap + swissAlti3D mosaic)

ESA MODULATE: Monte Mater, GSL-1, 14.10.2024 – 10.06.2025



7-months differential interferograms (car-based vs. SAOCOM)



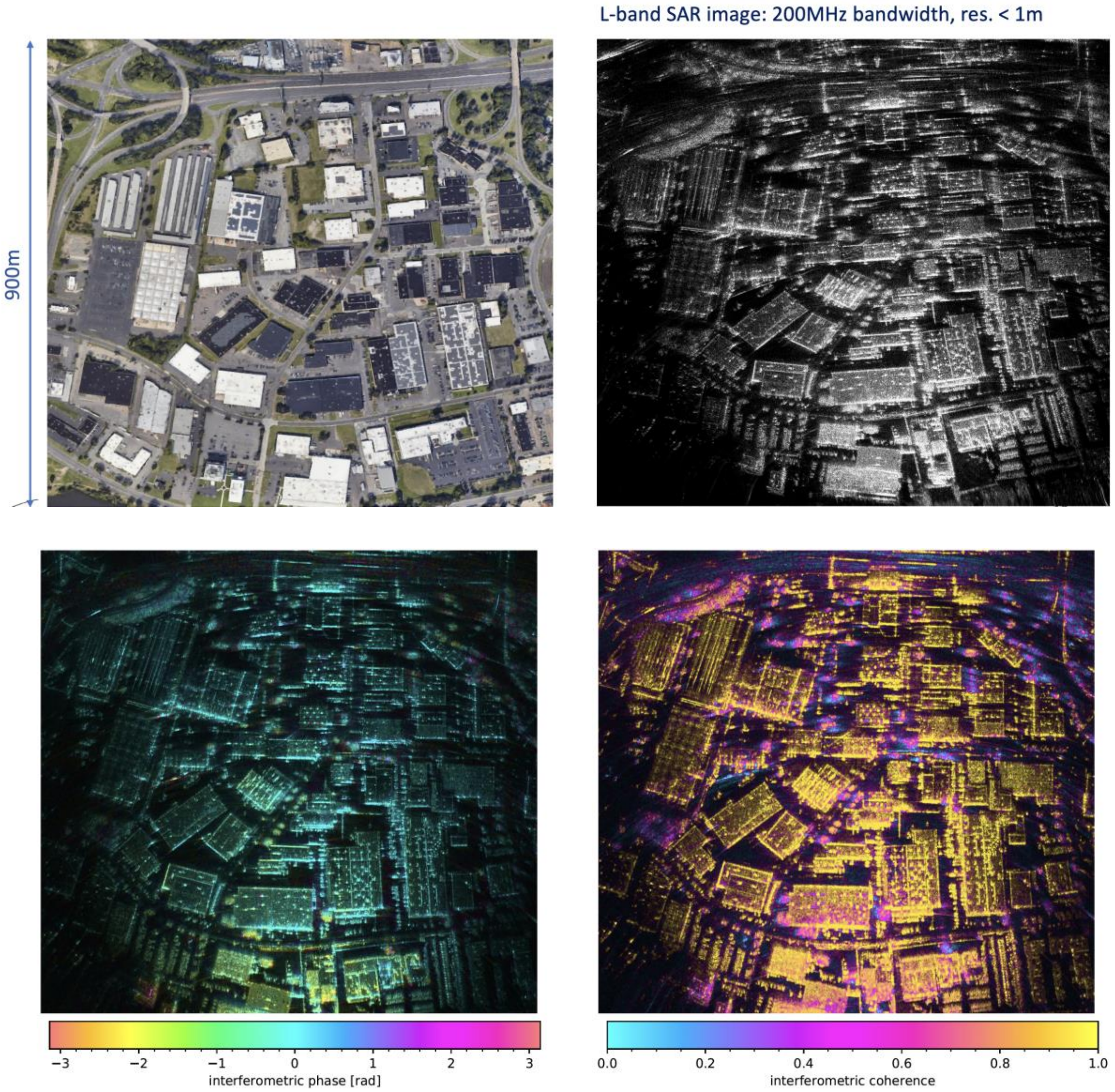


Strozzi, T., Jones, N., Agliardi, F., De Pedrini, A., Frey, O., Bernhard, P., Caduff, R., Ambrosi, C., and Manconi, A.: Monitoring the displacement of large alpine rock slope instabilities with L-band SAR interferometric techniques, *Nat. Hazards Earth Syst. Sci.*, 26, 2579–2607, https://doi.org/10.5194/nhess-26-2579-2026, 2026.

GAMMA REMOTE SENSING

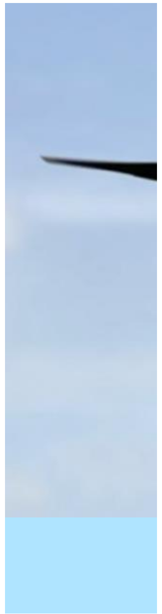
Quad-copter UAV-borne SAR imaging and SAR interferometry at L-band:

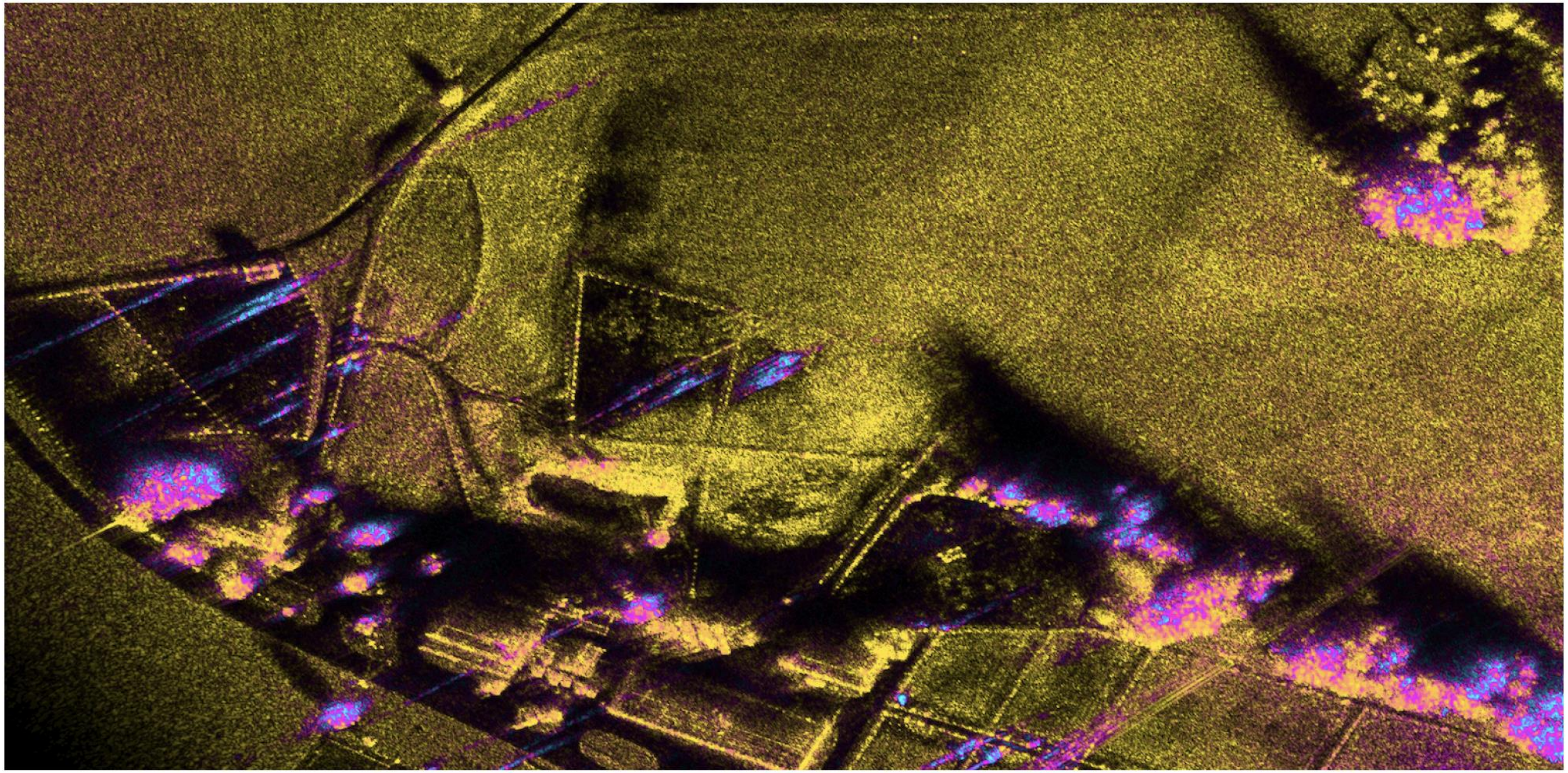
- **Gamma L-band SAR (GLSAR) with ,**
  more compact and light-weight form factor
- Down-sized L-band SAR with:
  - total payload : 6.5 kg
  - for quadcopter drones
  - and other platforms (airborne, HAPS w/ modification…)
- **Built-in GNSS/INS System : Honeywell HGuide n500**

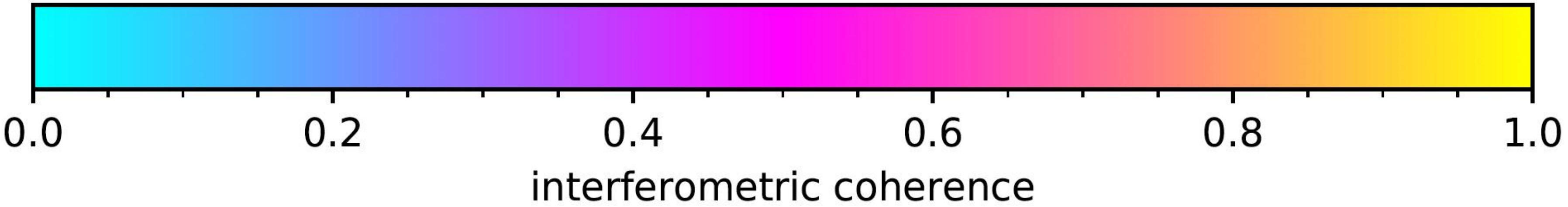


UAV-borne SAR imaging and interferometry with the 400MHz-bandwidth Gamma S-band SAR

Zoomed view: coherence (5-min repeat-pass)







GAMMA REMO

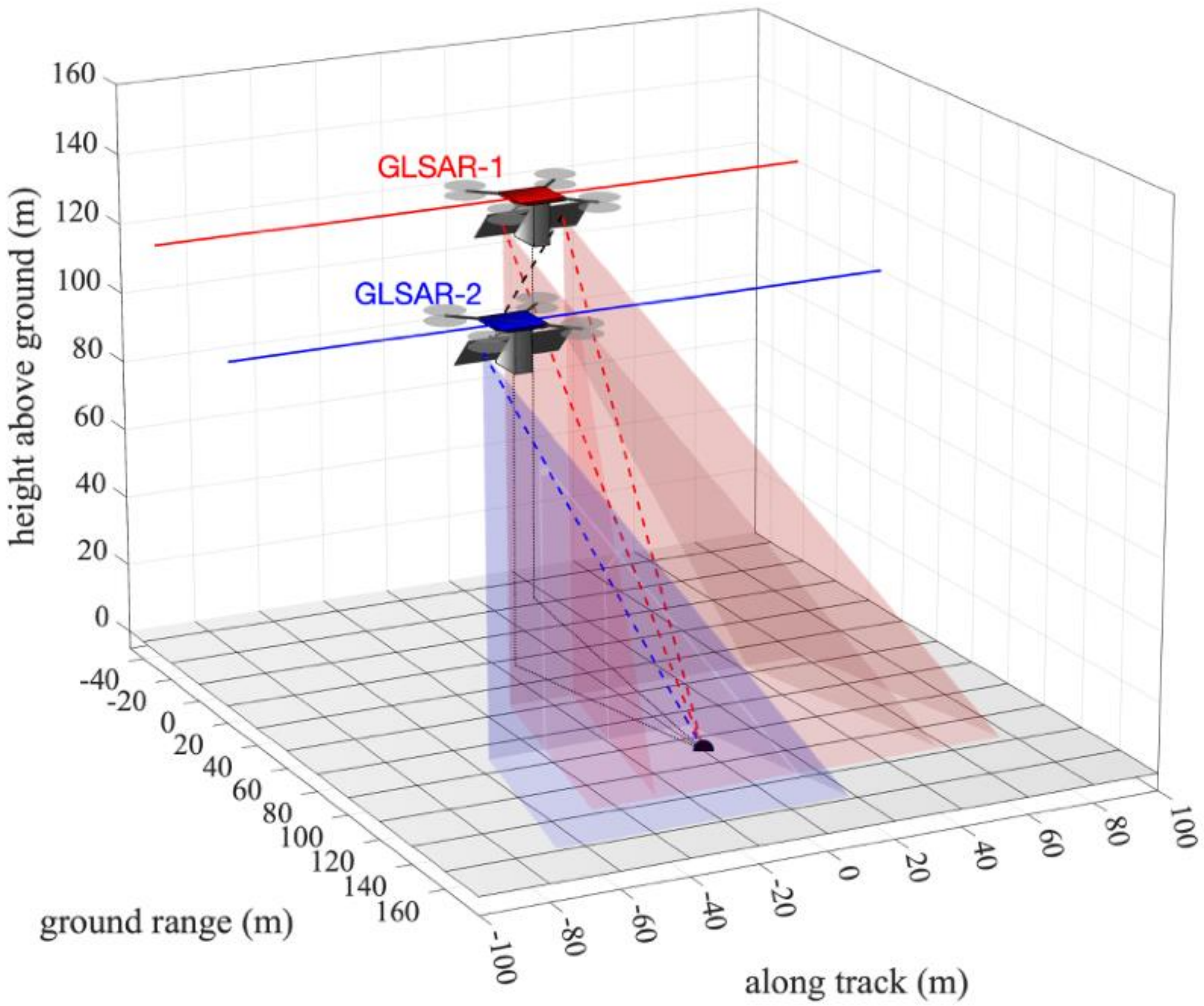
First UAV-borne **bistatic** campaign with 2 Gamma L-band SARs in May 2025

Two GLSAR systems on two Harris HX8 before takeoff and in air during the bistatic campaign in Norwich, Vermont, near CRREL, Hanover, New Hampshire

Motivation for bistatic SAR campaigns

- Bistatic SAR enables single-pass interferometric observations with
  - cross-track or along-track baselines from space,
  - supporting diverse geoscience applications, including
    1) topographic mapping
    2) vegetation structure retrieval
    3) three-dimensional ground motion estimation
- Mission concepts employing such acquisitions include
  - ESA's SAOCOM Companion Satellite,
  - co-flier concepts for ROSE-L and NISAR,
  - LuTan-1 in its bistatic phase,
  - upcoming ESA Earth Explorer mission Harmony (2 passive companions with a Sentinel-1 satellite).
- Once established, UAV-based bistatic SAR provides a flexible means to explore and validate these concepts.
- Beyond concept demonstration, UAV- and airborne systems can support the validation of geo- and biophysical retrievals of bistatic space missions.

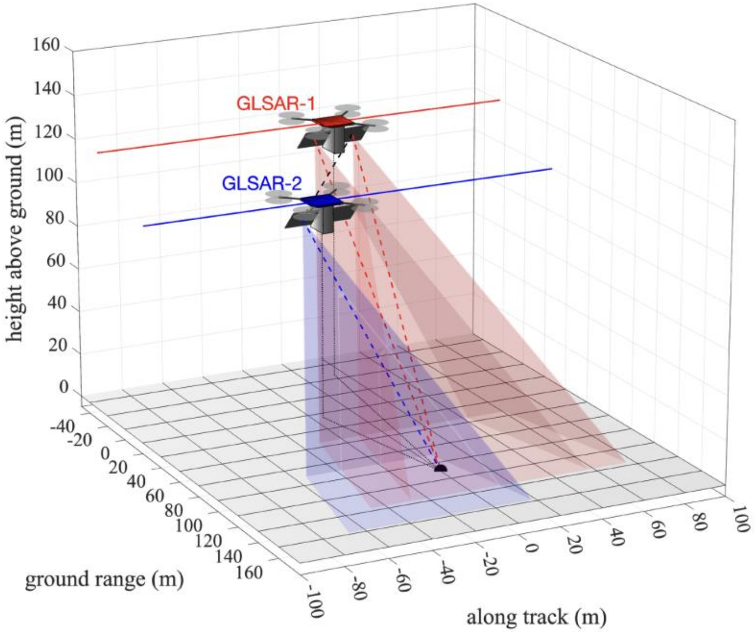
First UAV-borne **bistatic** campaign w/ Gamma L-band SARs in May 2025

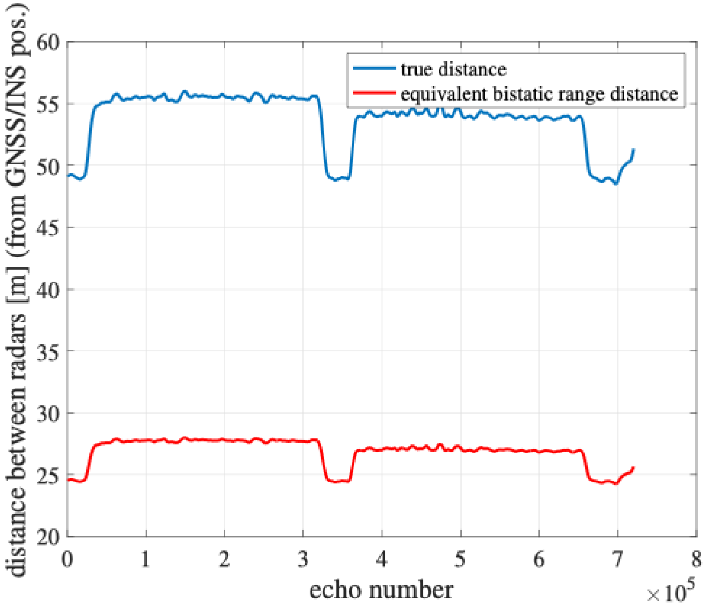


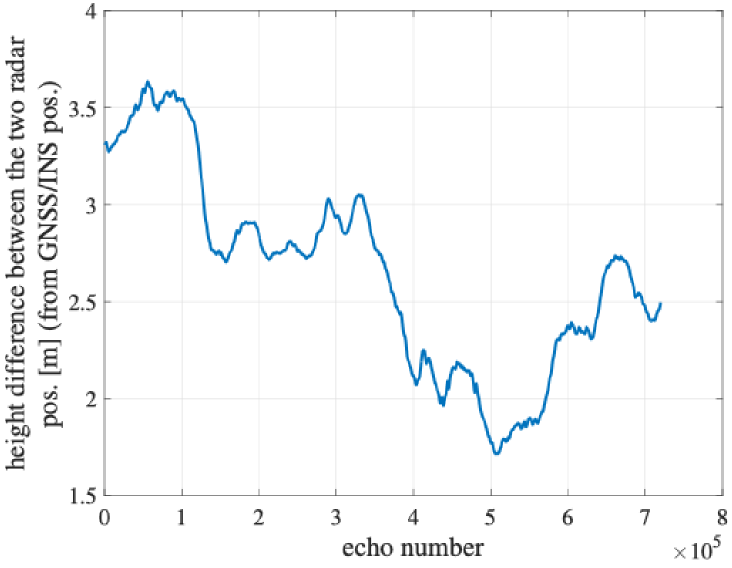
Basic bistatic measurement concept used:

- 2 GLSAR systems, each equipped with a GPSDO with time synchronization on the order of 30ns (PPS accuracy)
- + direct signal received through back-lobe of GLSAR-2 receive antenna
- requires specific bistatic configuration, as direct signal is superposed with bistatic SAR backscatter data and should appear between 0m and the nadir return to be separable

First UAV-borne bistatic campaign w/ Gamma L-band SARs in May 2025







First UAV-borne bistatic campaign w/ Gamma L-band SARs in May 2025

(Preliminary) bistatic SAR image

- no synchronization & phase calibration, yet just GNSS/PPS-disciplined oscillators

➔ image is
  - shifted
  - defocused

Monostatic image

Bistatic image after transmitter

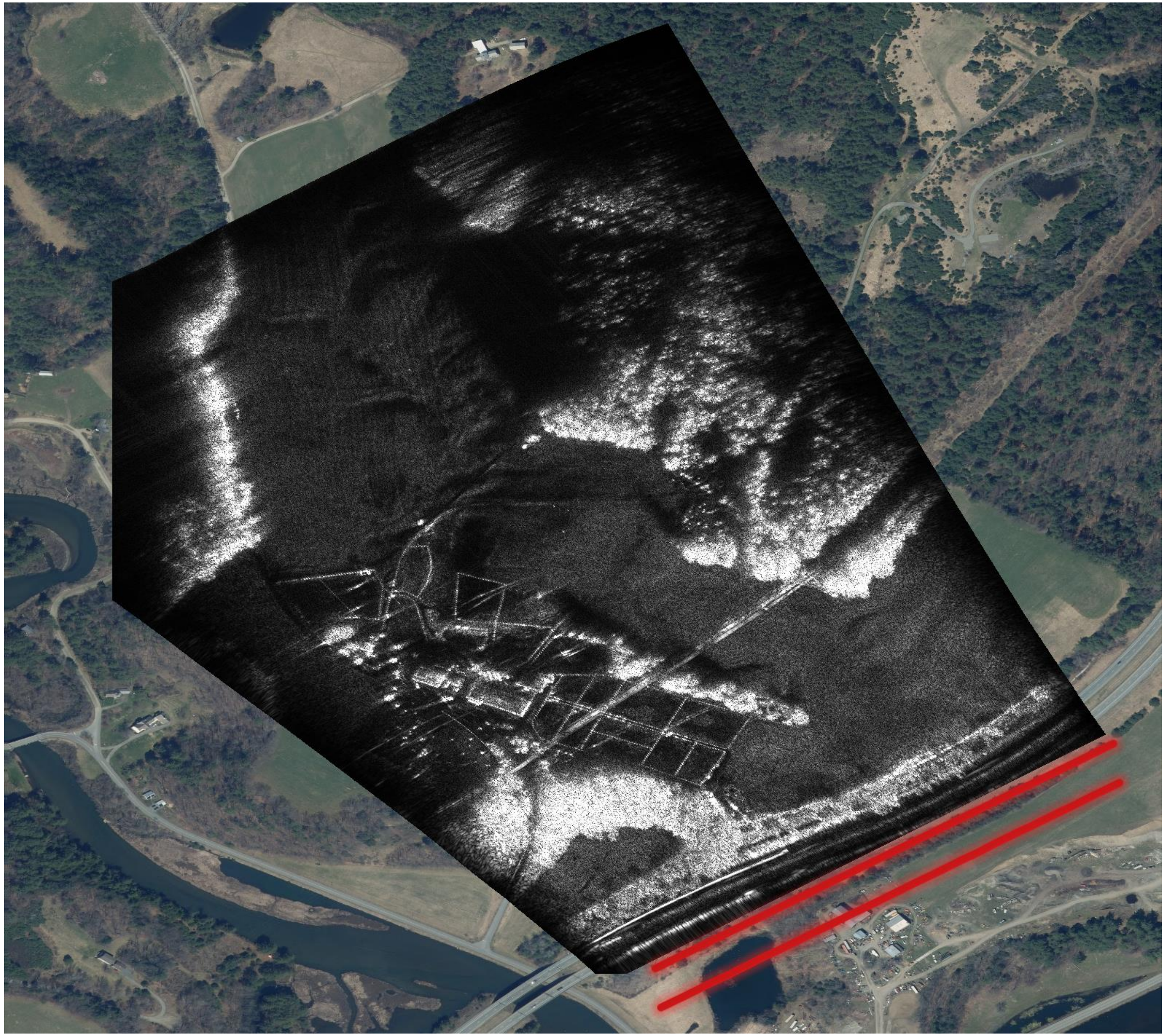
Bistatic image after compensation of a timing offset:

- Specs of GPSDO: PPS accuracy: 30ns

➔ Compensated shift is much larger: around 33m

Also:
No compensation of phase drifts along azimuth, yet.

Work in progress…



GAMMA REMOTE SENSING

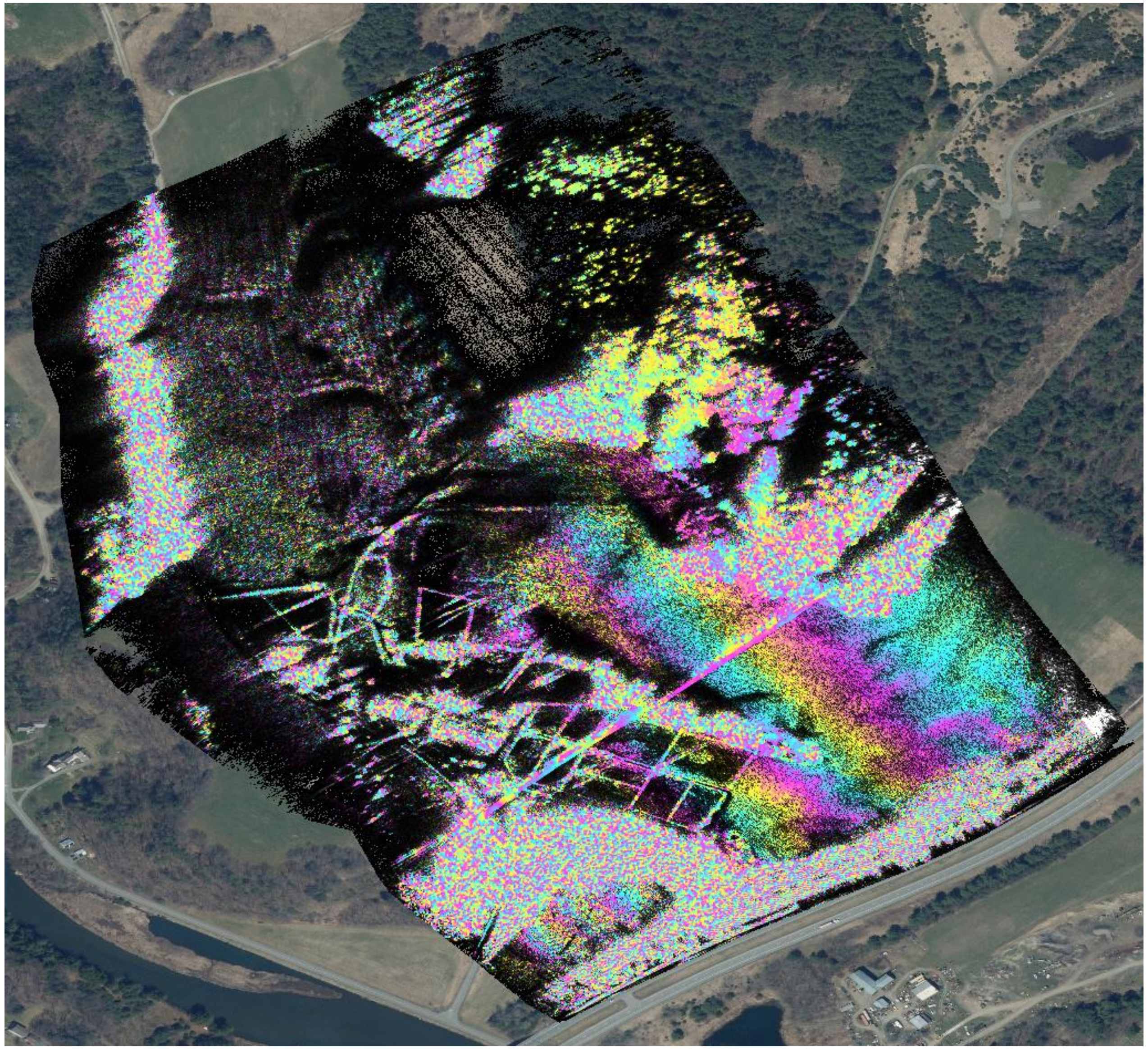
First UAV-borne bistatic campaign w/ Gamma L-band SARs in May 2025

Single-pass bistatic diff. phase

- clear zero phase map
- (except forest/trees and buildings)
- confirming the excellent repeat-pass capability of the UAV-borne GLSAR system (e.g. for ground motion)

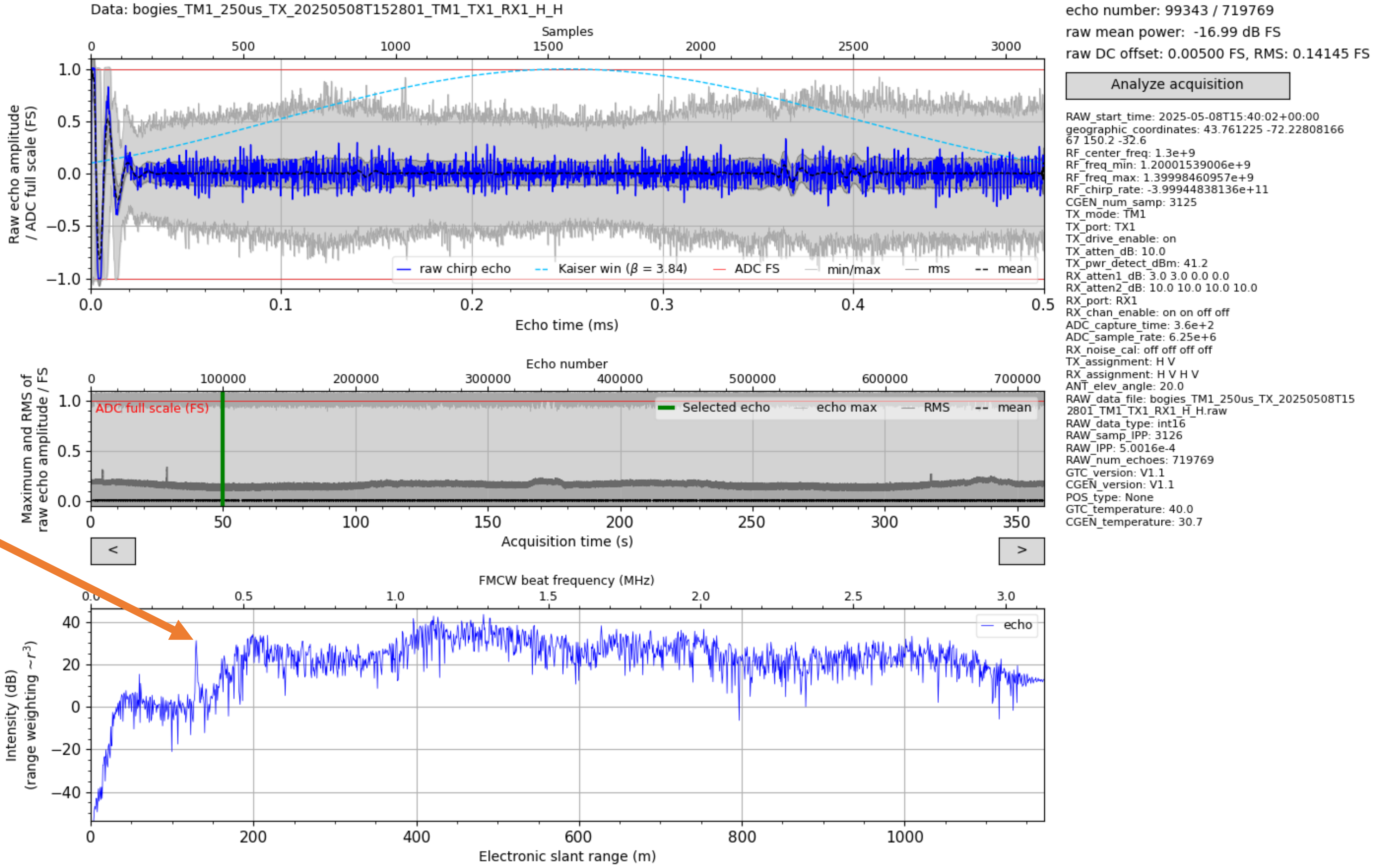
Repeat-pass diff. phase (first & back)

- phase trend in azimuth
- due to imperfect/unstable bistatic signal sync.
- is confirmed with the direct signal
    - hardly detectable
    - it is also visible in the region of the FMCW ADC conversion
    - because of 35m shift (random, GPSDO timing error)

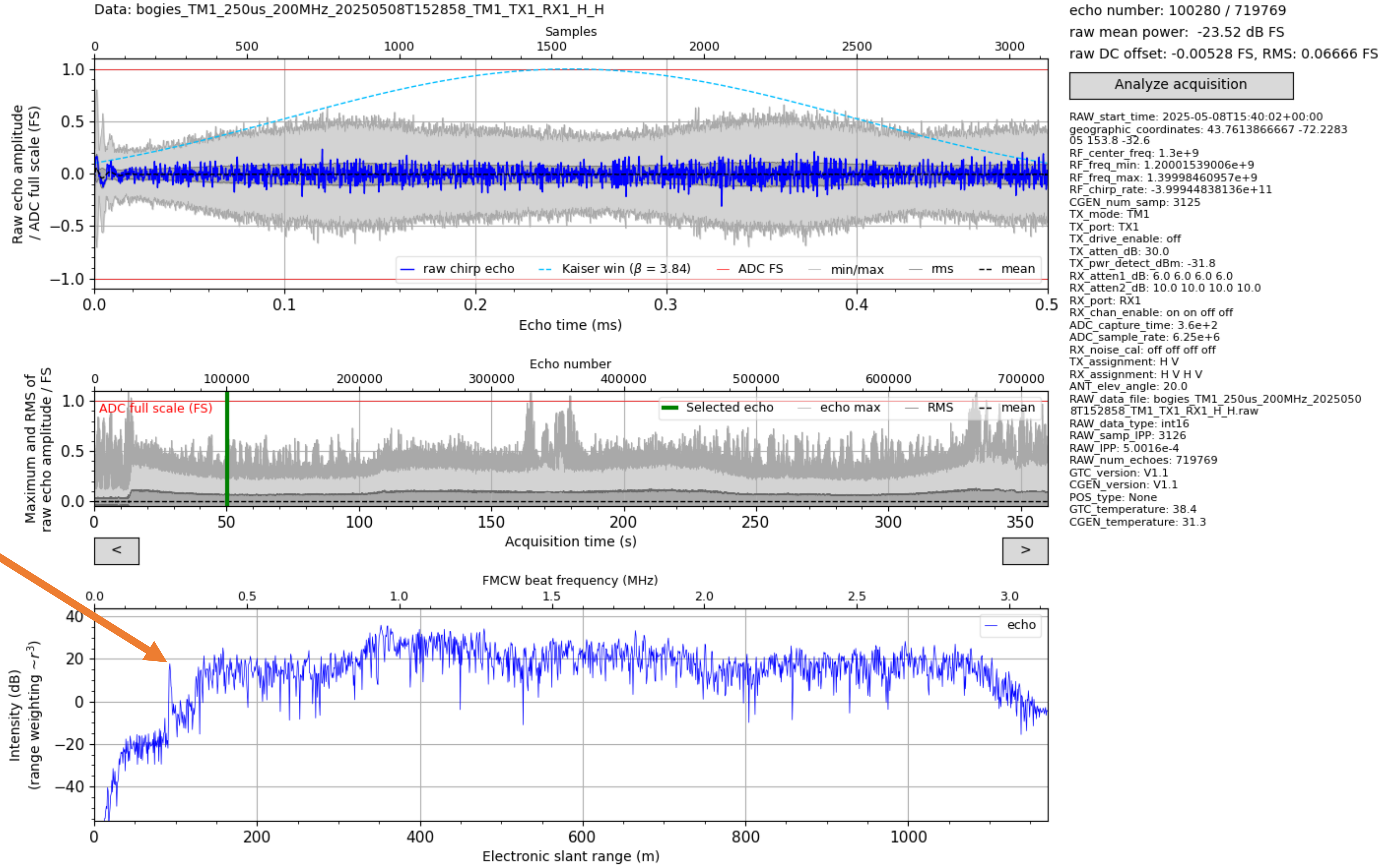


Monostatic Received Signal

nadir return



Bistatic Received Signal

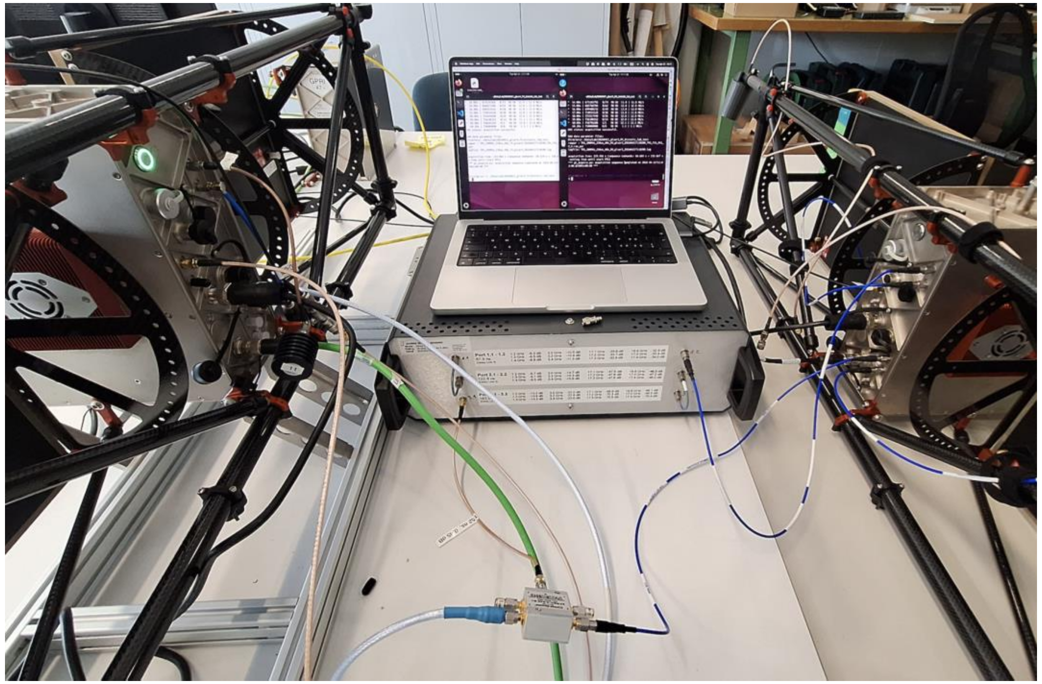


nadir return
shifted
by 35m

GAMMA REMOTE SENSING

“Bistatic” delay-line lab measurements

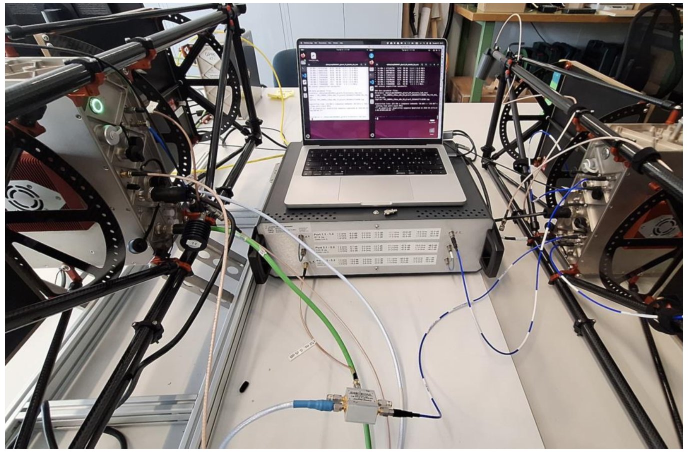
”Bistatic” delay line
TX: GLSAR-4
RX: GLSAR-5



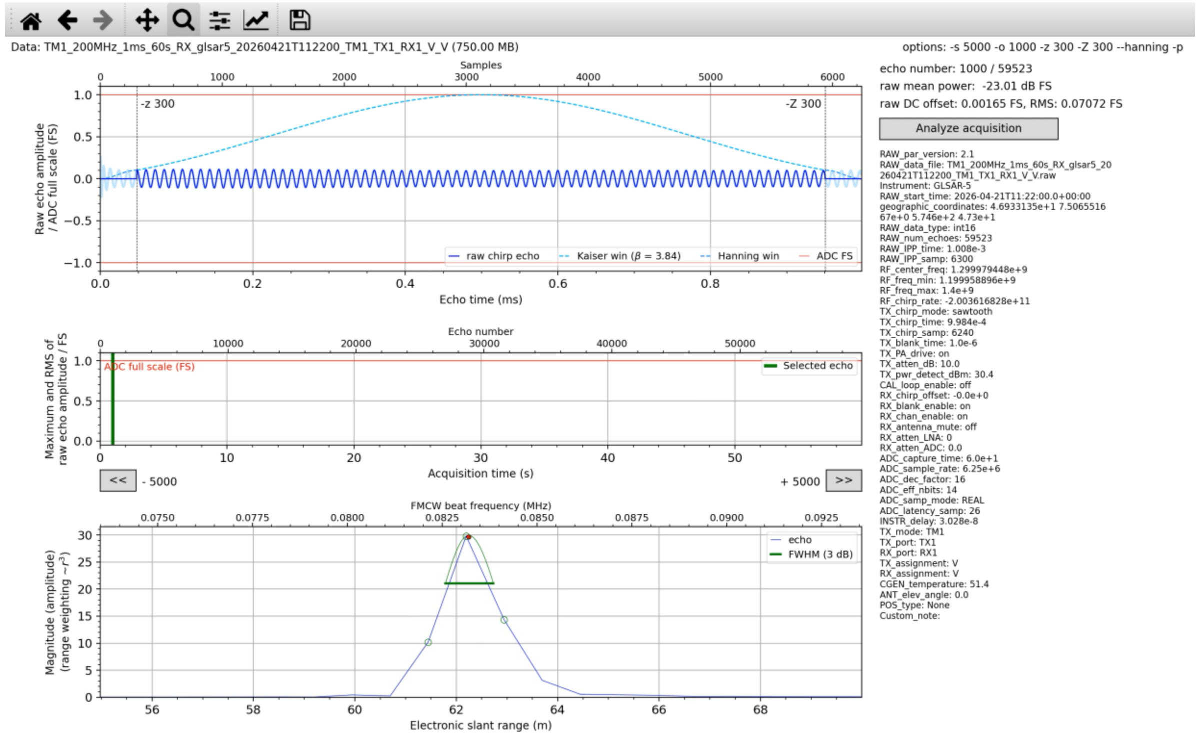
”monostatic” delay line
TX: GLSAR-4
RX: GLSAR-4

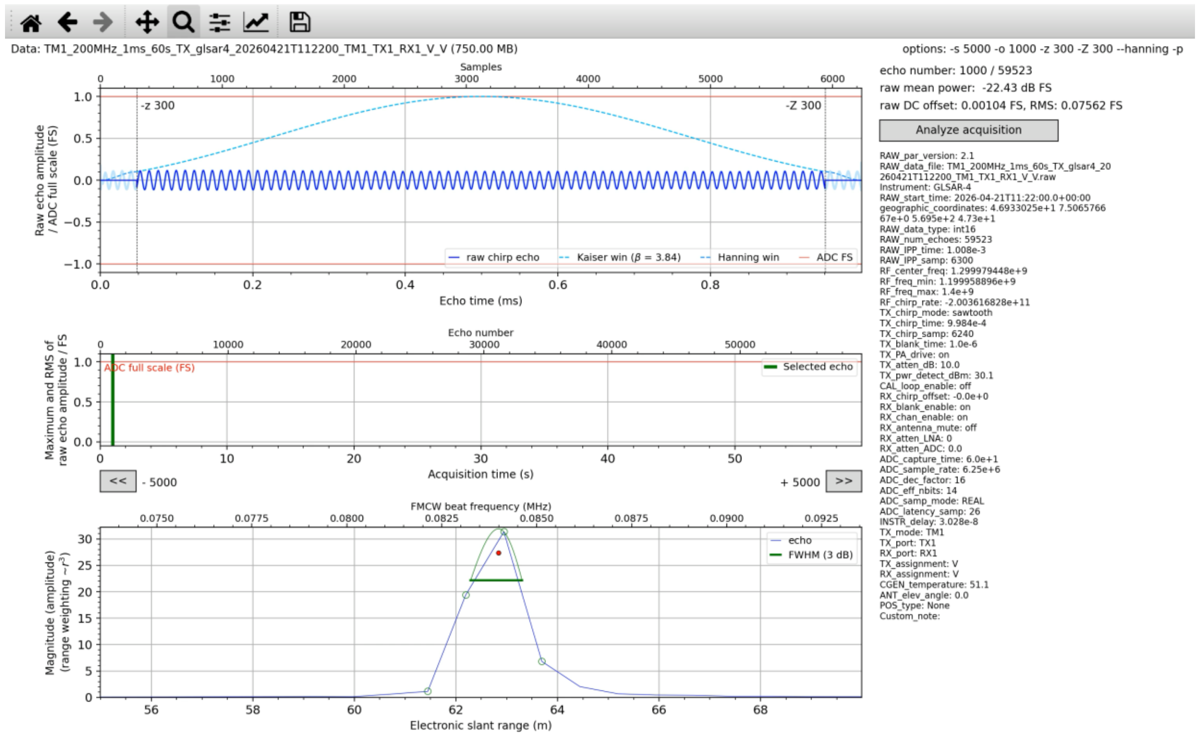
“Bistatic” delay-line lab measurements

”Bistatic” delay line
TX: GLSAR-4
RX: GLSAR-5



”monostatic” delay line
TX: GLSAR-4
RX: GLSAR-4





“Bistatic” delay-line lab measurements

”Bistatic” delay line
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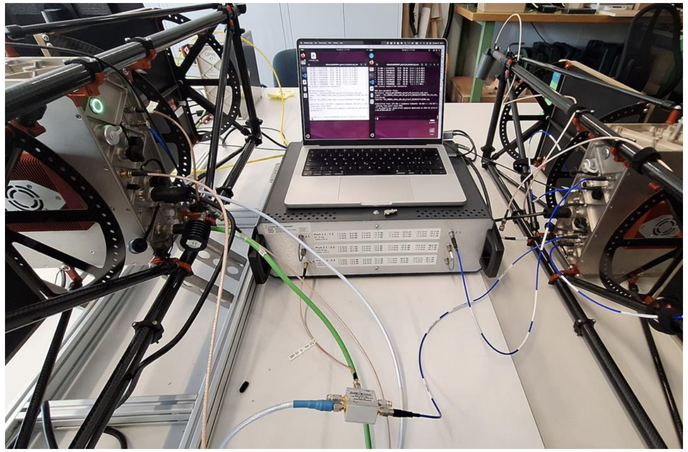
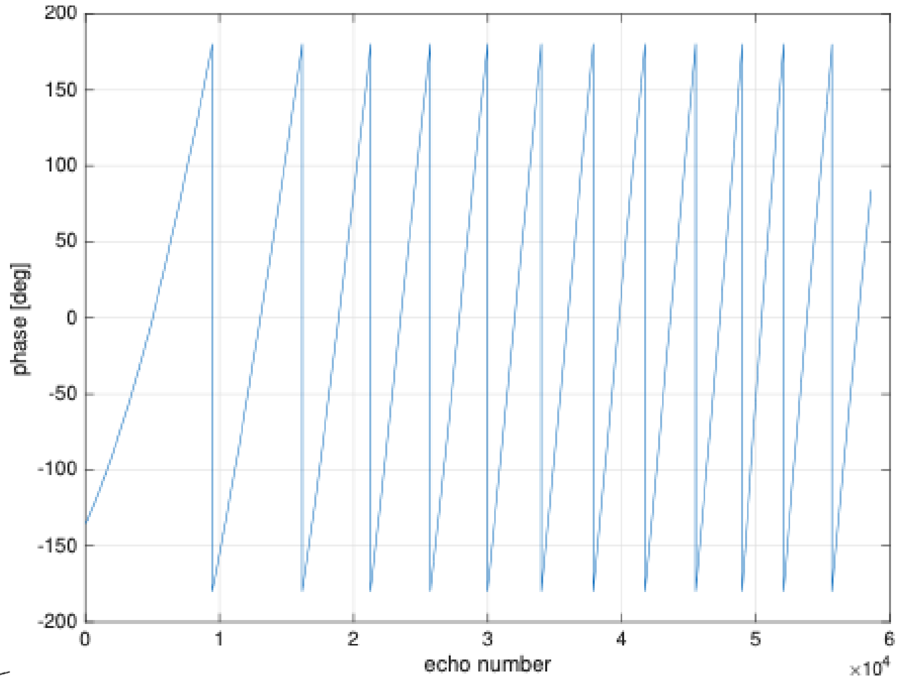
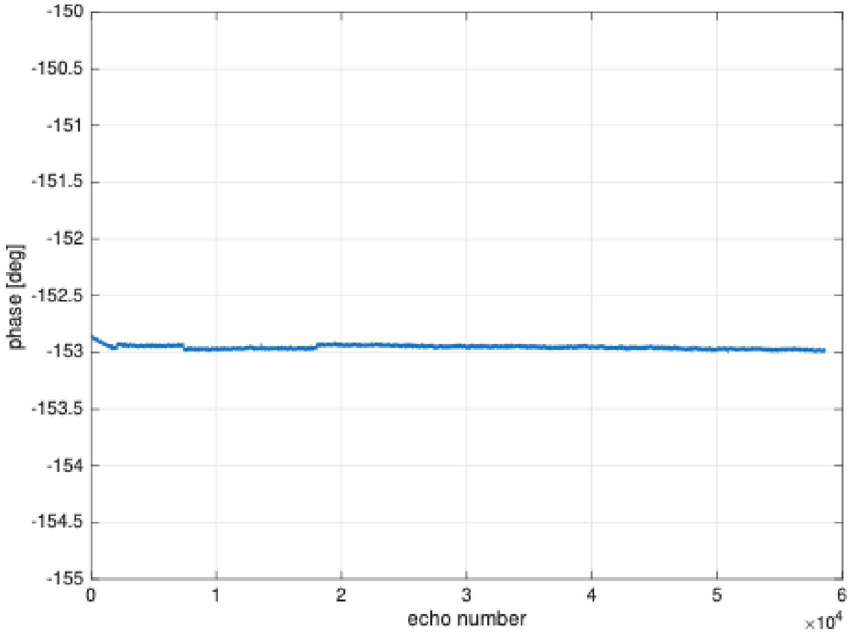


”monostatic” delay line
TX: GLSAR-4
RX: GLSAR-4





“Bistatic” delay-line lab measurements

”Bistatic” delay line
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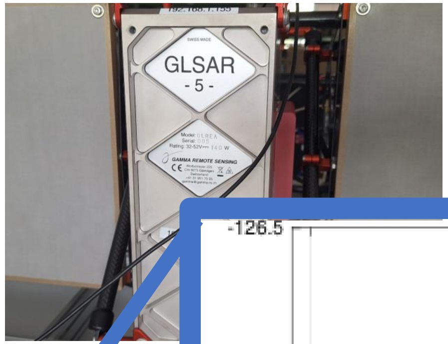
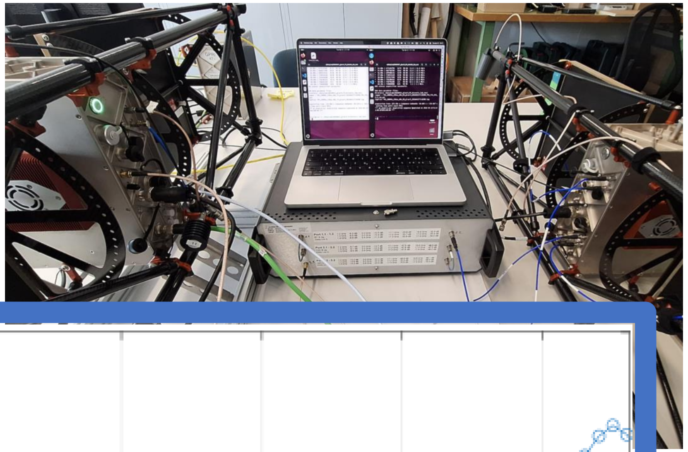
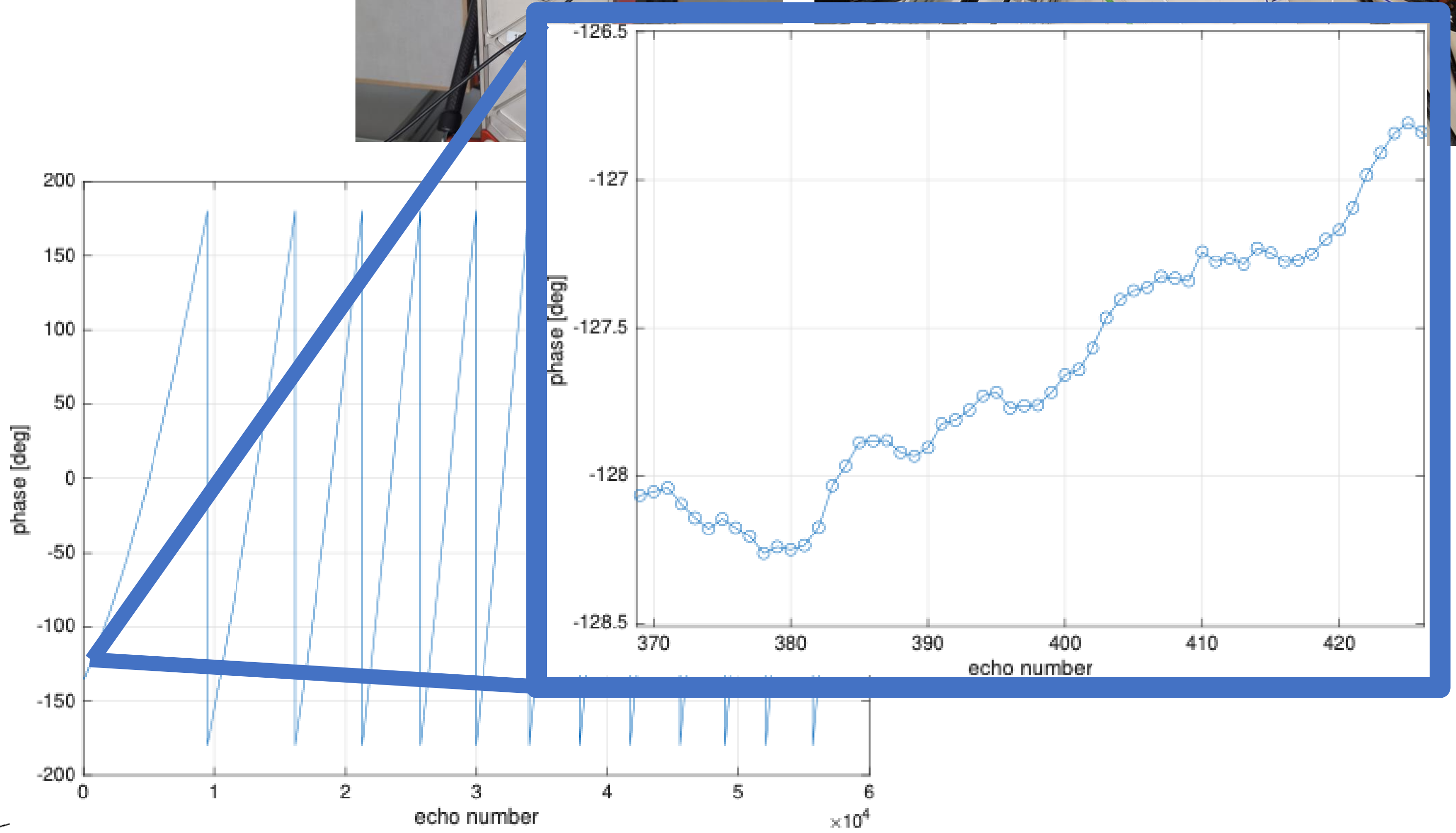
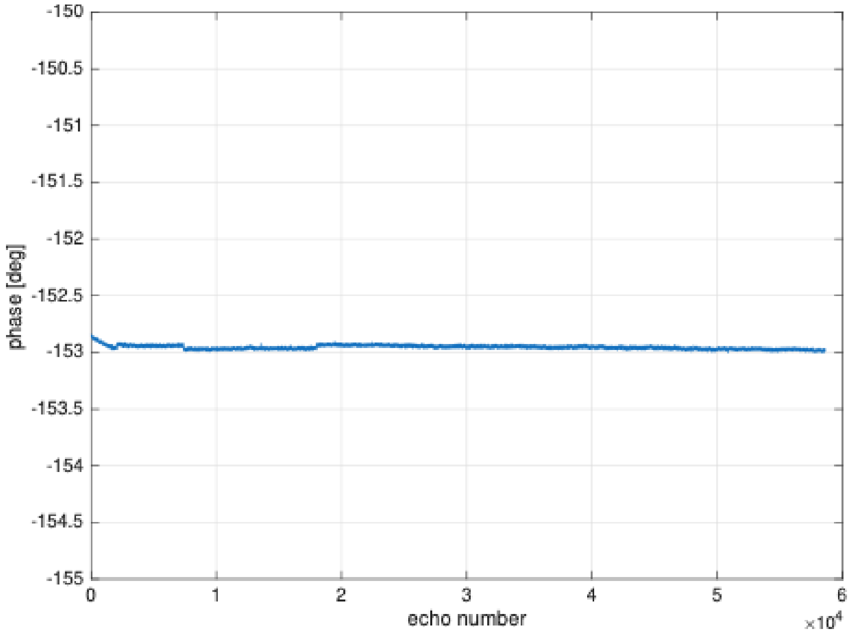
RX: GLSAR-5





”monostatic” delay line
TX: GLSAR-4
RX: GLSAR-4



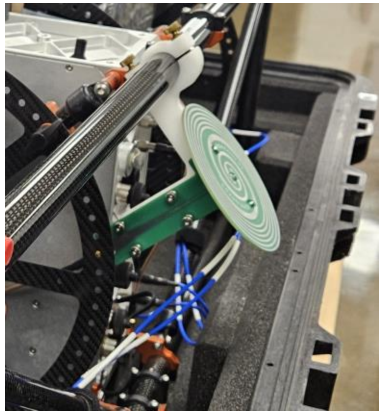


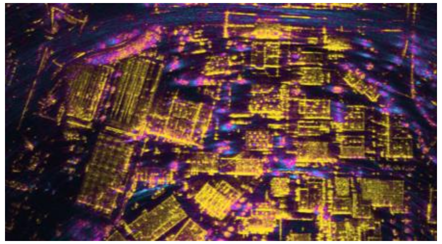
Summary / Outlook

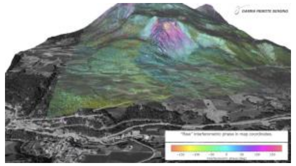
1. UAV-based **SAR imaging** demonstrated for Gamma L-/S-band SAR & car-based SAR imaging for L-/S-/Ku-band

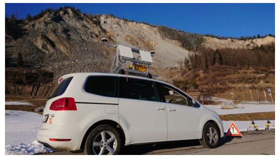
2. UAV-based **repeat-pass SAR interferometry** demonstrated for L-/S-band & car-based DInSAR for L-/S-/Ku-band

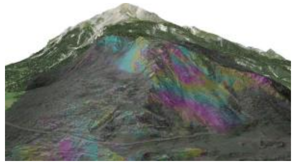
3. UAV-based **bistatic imaging and interferometry**:







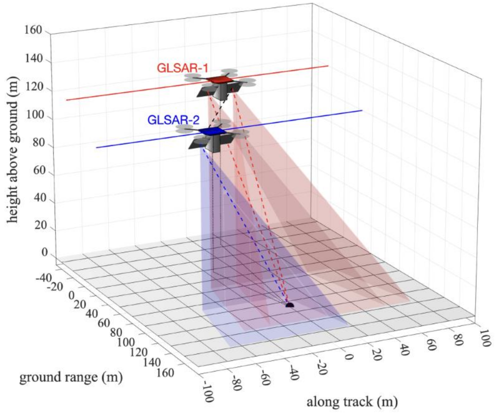


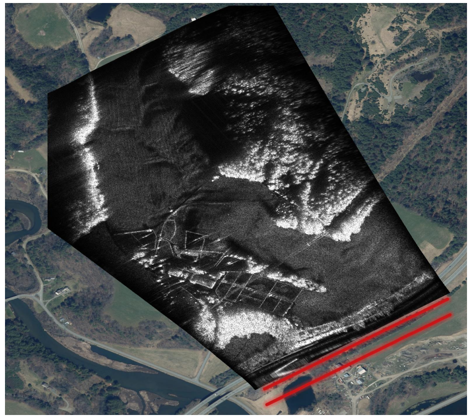


Work in progress…

next steps:

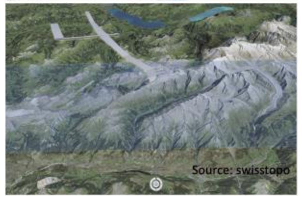
- improved experimental setup (summer 2026) to
    - allow synchronization via direct signal to
    - remove azimuth-varying phase with
        - wide-beamwidth receiving antenna oriented towards the Tx for the direct signal
          ➔ recorded in a separate receive channel
        - increased distance between Tx and bistatic Rx to ensure detection of direct signal
        - minimized along-track positioning offset for interferometric acquisitions
        - higher Tx flight level (200m instead of 100m)





Broader Outlook:

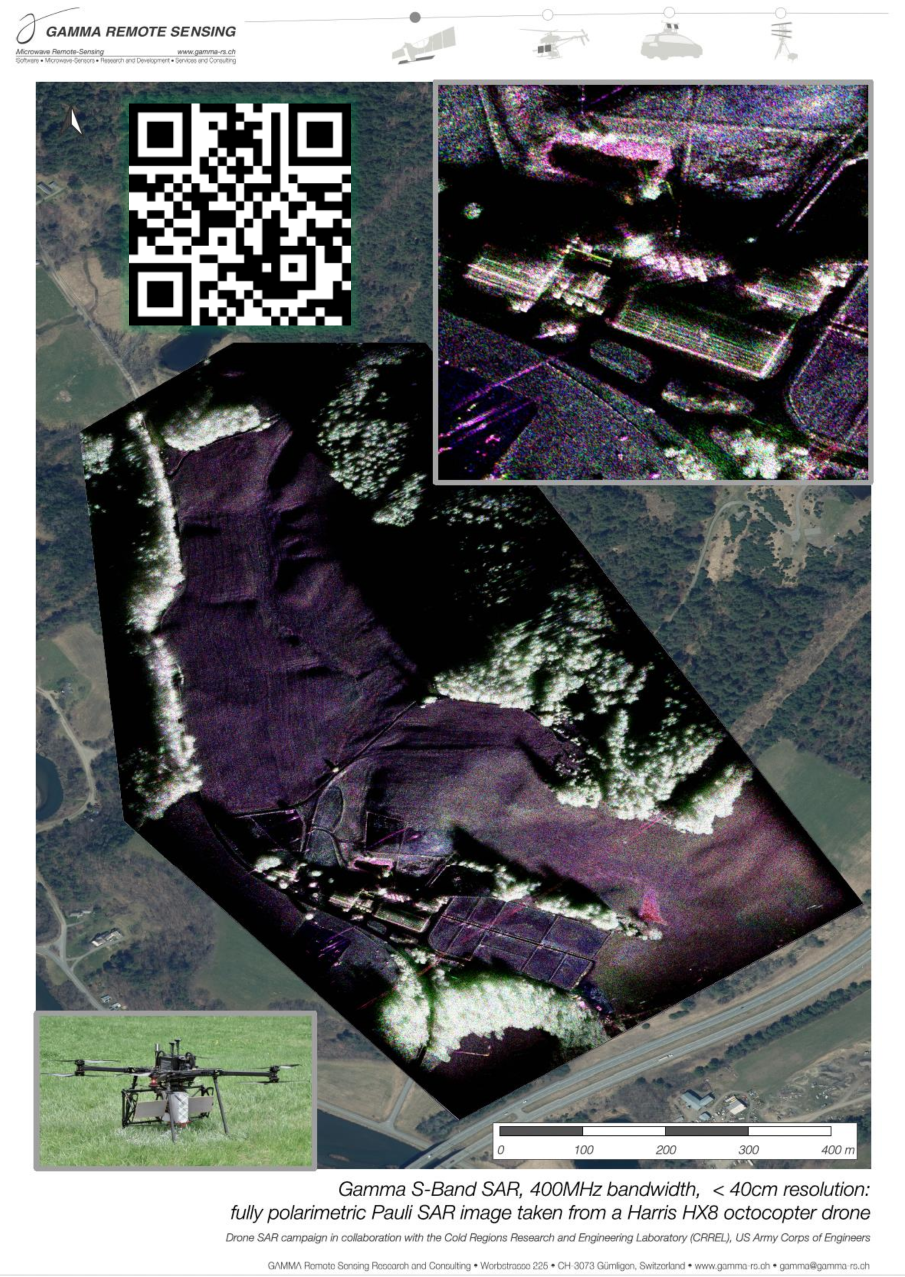
- integration of a Gamma S-Band SAR system
    - on a manned aircraft with first flights/images in Nov 2025 and a more recent update in May 2026
    - on a HAPS/HALE is in discussion



Thank you!

frey@gamma-rs.ch

https://www.gamma-rs.ch/instruments



https://tinyurl.com/3xxrphsc

GAMMA REMOTE SENSING