Building a National SAR Target Infrastructure in Sweden: Supporting EGMS and New SAR Calibration and Validation Opportunities

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Sweden's Geodetic Infrastructure: A Multi-Technique Approach

- Permanent GNSS stations (SWEPOS™) (active network)
- Geodetic consolidation GNSS points (försäkringspunkter, passive)
- Height & Gravity Control points (passive)
- Tide gauges/Mareographs (active)
- **Onsala Space observatory**: Fundamental Geodetic Site (passive and active)

  GNSS, VLBI, SLR, Absolute Gravity, Tide gauge and Corner reflectors, …

- **Artificial SAR targets (passive + active) (Geodetic SAR/InSAR)**

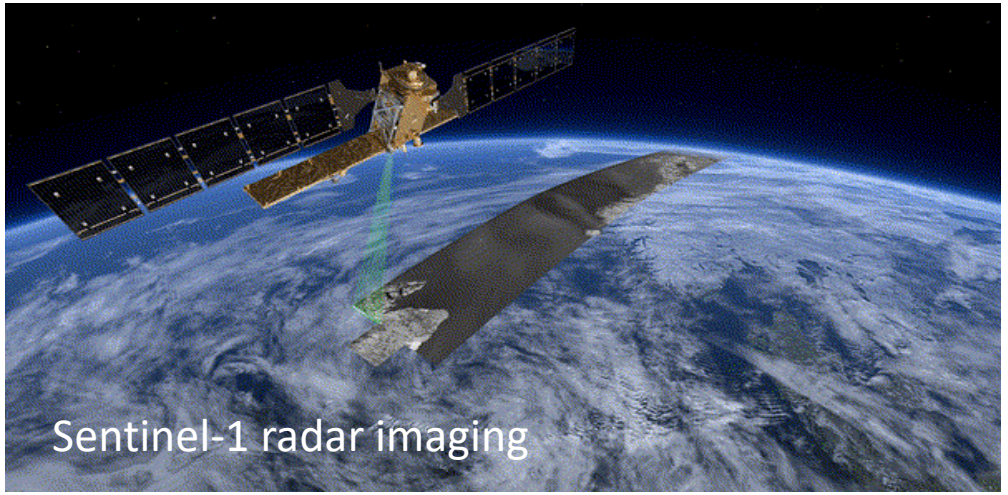
Corner Reflectors and Active Transponders co-located with GNSS stations

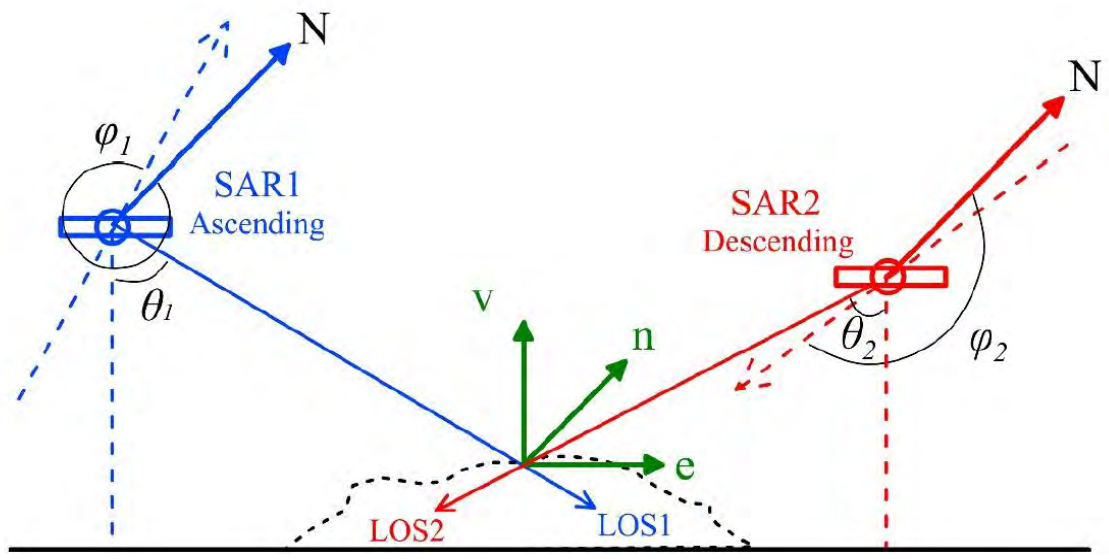
Corner reflectors + VLBI telescopes

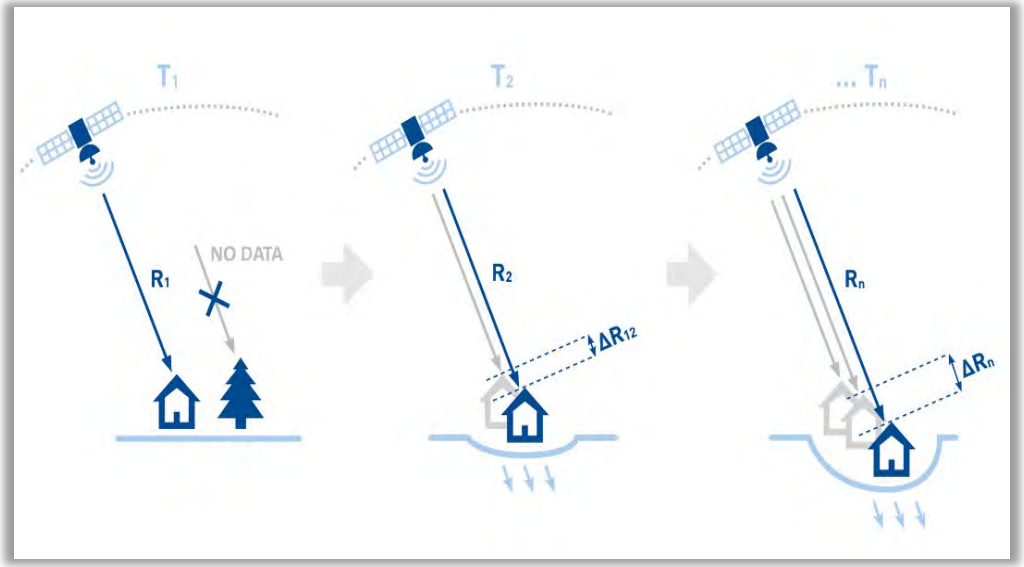
Combining passive and active geodetic networks to support static and dynamic reference frame realization and precise ground-motion monitoring.

InSAR (Interferometric Synthetic Aperture Radar)

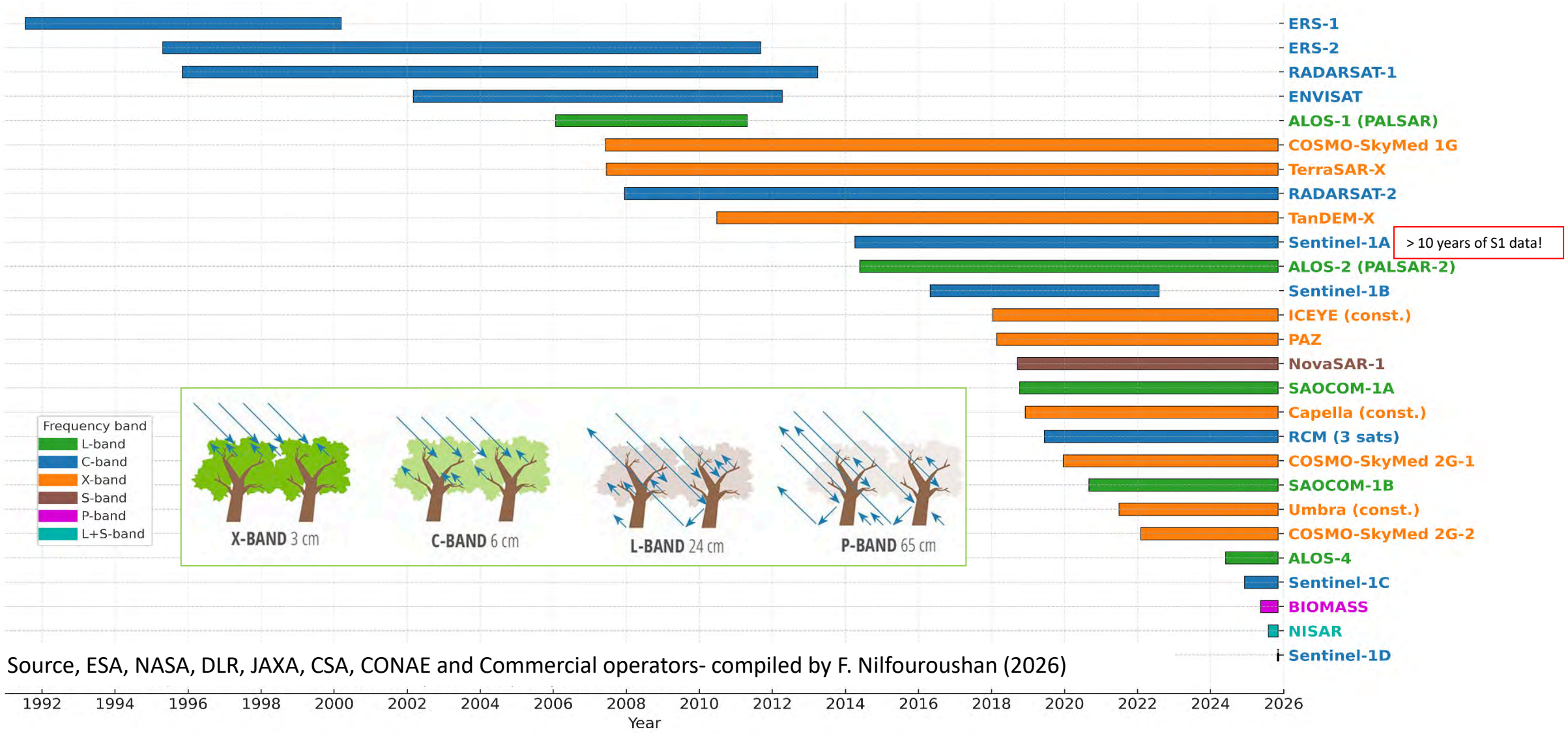
- **SAR** is a microwave radar used to measure ground motion.
- Active sensor, transmits its own signal and records the backscatter.
- All-weather capability – works day/night and through clouds.
- Repeated observations enable InSAR to detect millimeter-level ground movements.
- Measurements are along the **Line-of-Sight (LOS).**
- Ascending + descending passes help resolve **EW and UD** motion.





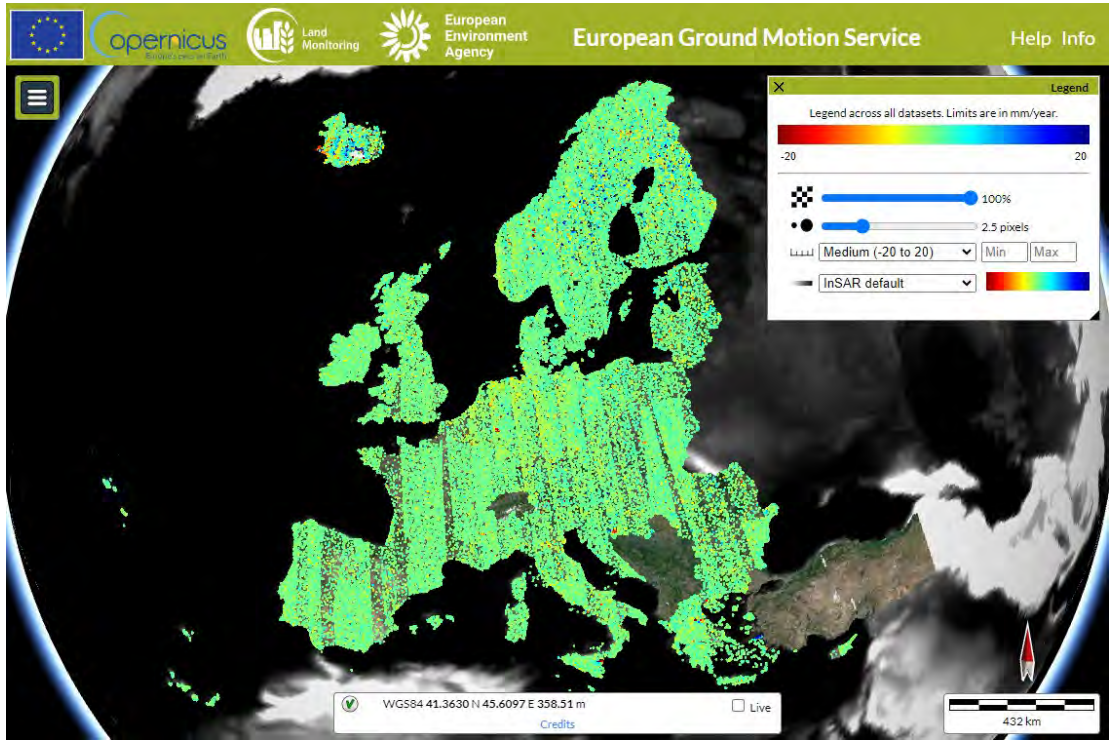


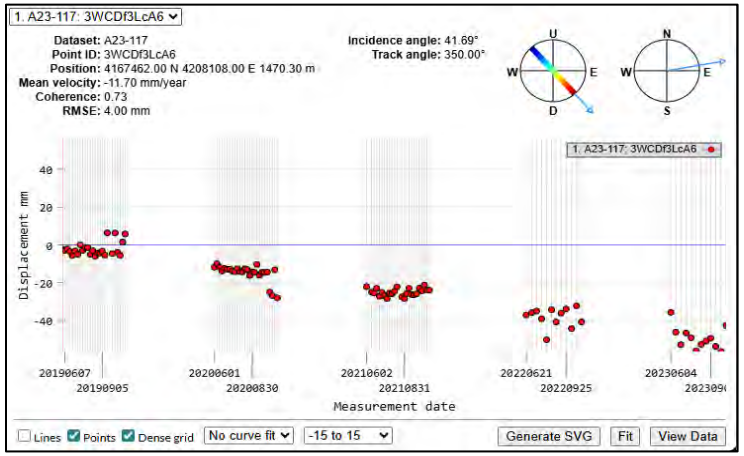
SAR Satellite Missions



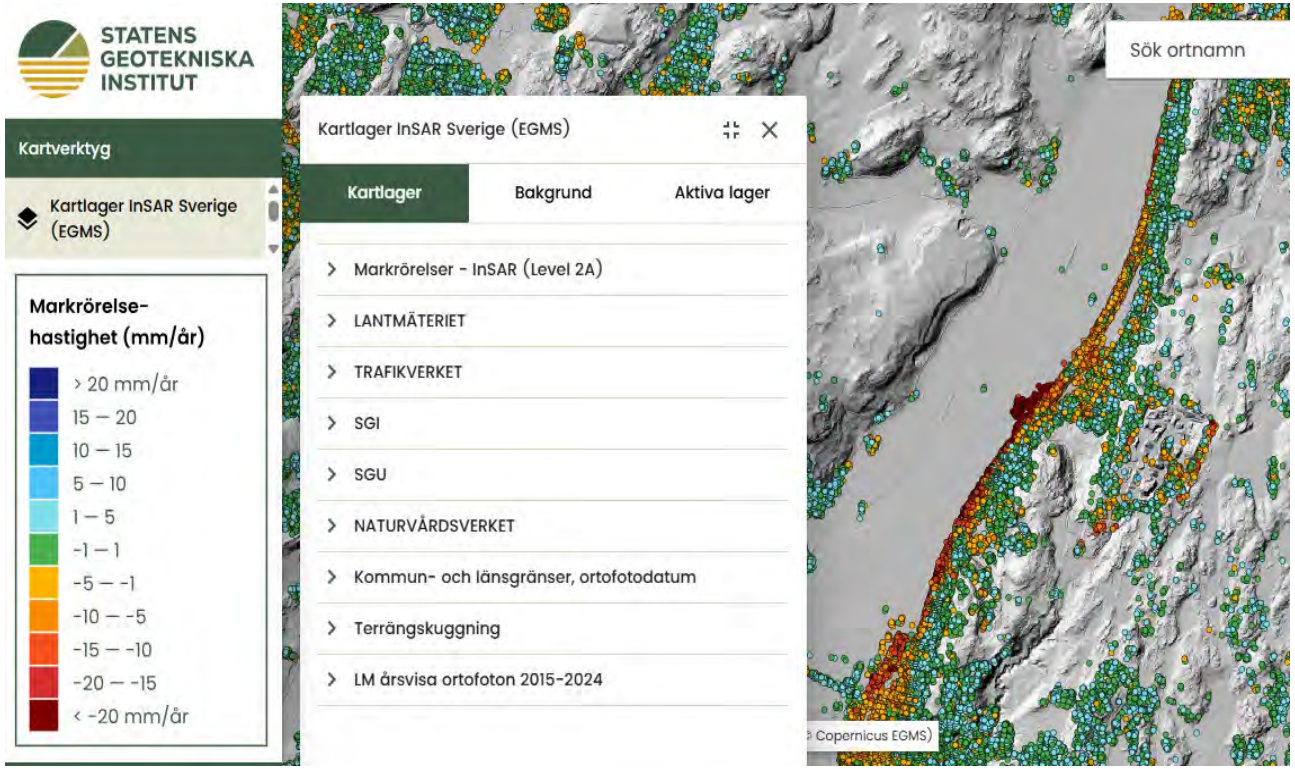
Source, ESA, NASA, DLR, JAXA, CSA, CONAE and Commercial operators- compiled by F. Nilfouroushan (2026)

EGMS and SGI New Web Service (EGMS-based)





https://egms.land.copernicus.eu/



InSAR Sverige (EGMS)

https://insar.sgi.se/

InSAR Sverige (EGMS)

A new national WebGIS platform, **“InSAR Sverige (EGMS)”**, has been developed by the **Swedish Geotechnical Institute (SGI)** and is freely accessible to all users.

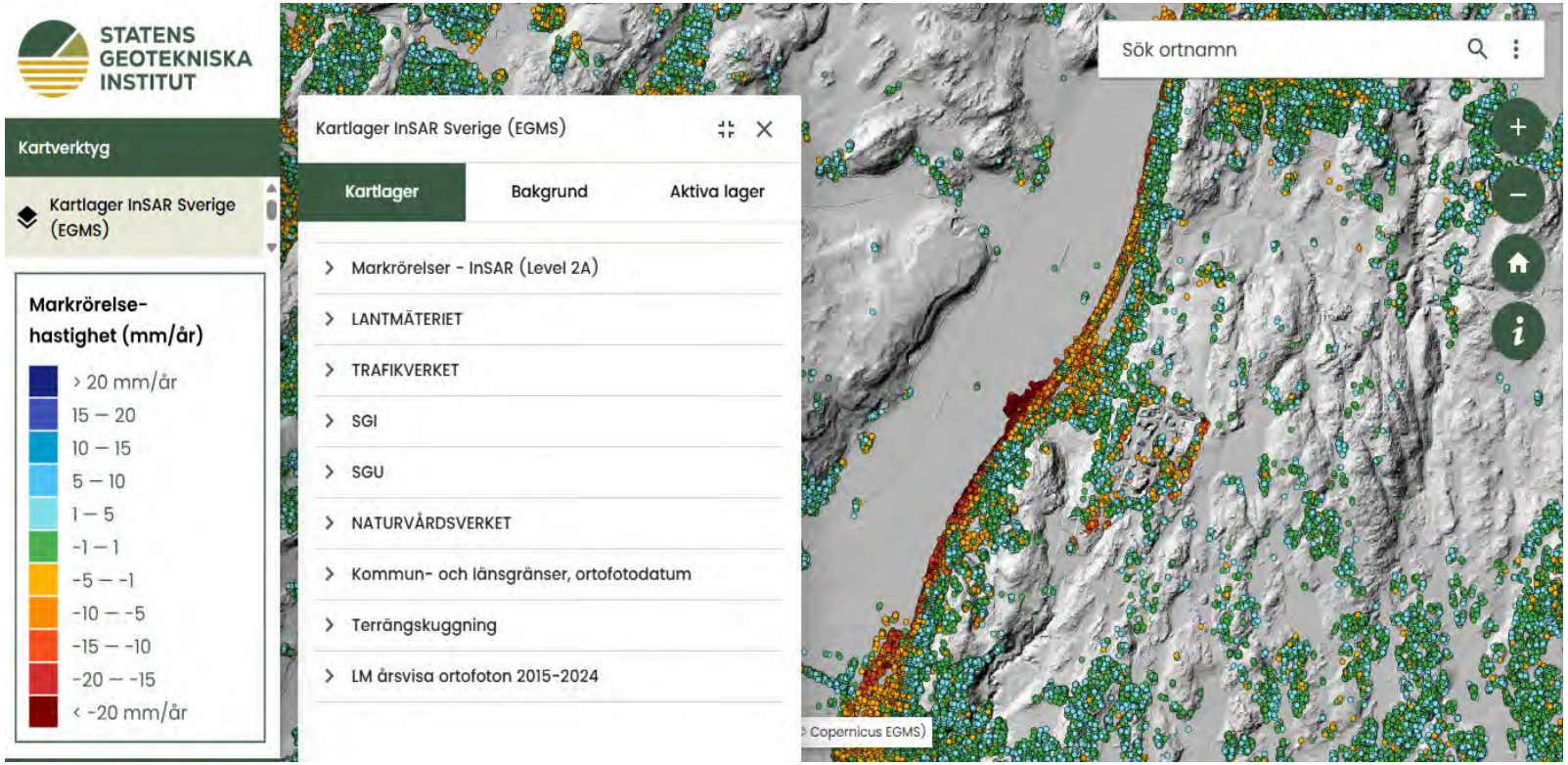
Integrated datasets include:

EGMS InSAR ground-motion products
High-resolution orthophotos (0.5 m and 0.16 m)
Historical orthophotos (2015–2024)
Thematic datasets from national authorities *(Lantmäteriet, Trafikverket, SGI, SGU, Naturvårdsverket)*

Filtering of EGMS data by velocity range (PS points).

Current status

EGMS Basic products included; two releases currently available. Additional releases and product types (e.g., Ortho) will be added in future.



https://insar.sgi.se/

Open access since yesterday (10 March).

Lantmäteriet was part of the reference group and contributed to both the initiation of the idea and the development of the service.

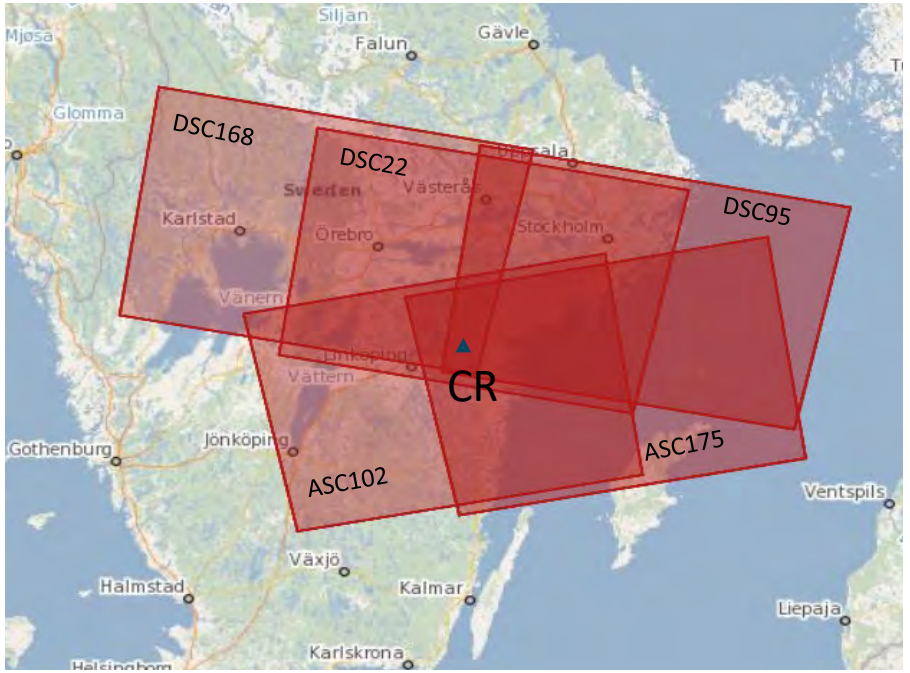
Why artificial SAR targets?

- **Calibration and validation of InSAR products,** e.g., EGMS products
- Link between InSAR and other techniques (e.g., GNSS); **make InSAR "absolute"**

- Provide coherent radar measurement point **at desired location** to monitor the ground movements with InSAR technique.

- **Improve spatial sampling** in areas where there are **no natural (rocks, buildings, roads)** persistent scatterers

- **Connect InSAR and other techniques**
  - Connection between different tracks of the same InSAR system,
  - Connection between different InSAR systems



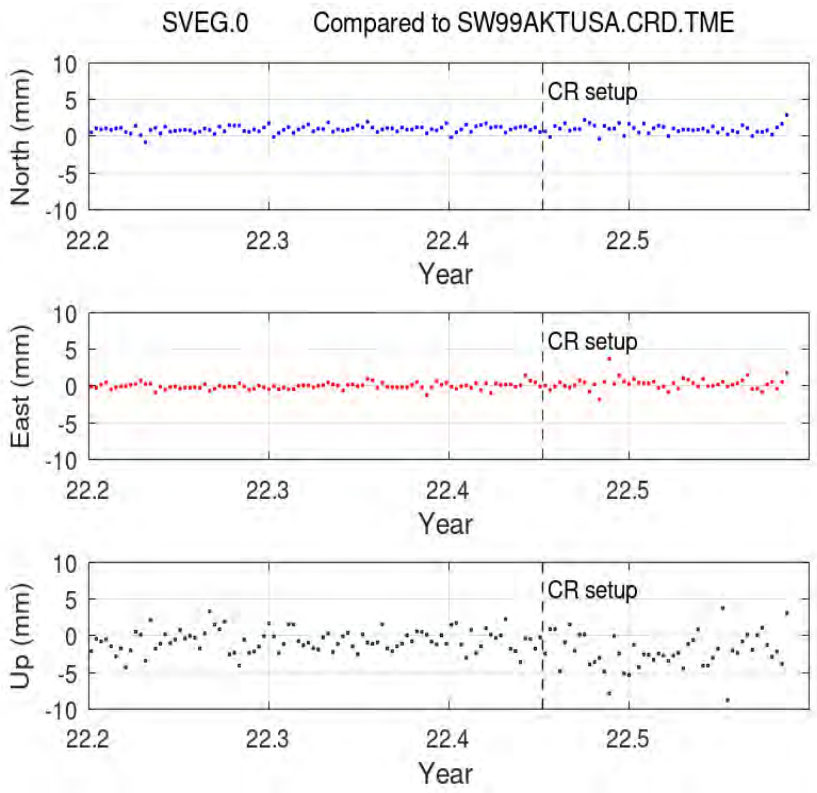
Installation and data analysis, 2020-2026

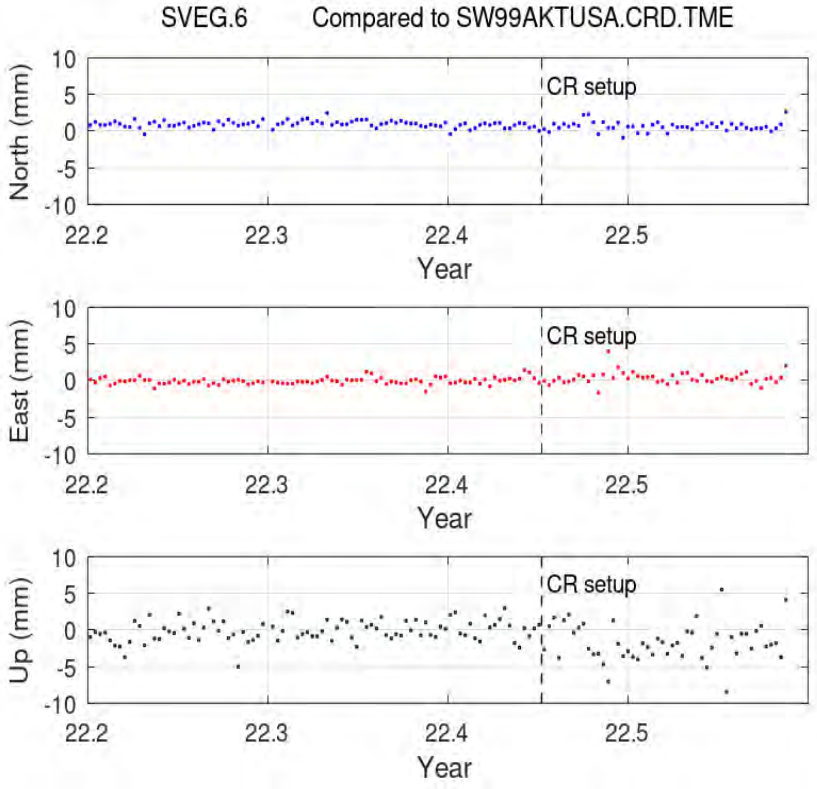
Two types: Passive: **corner reflectors** and Active **Transponders (CAT)**

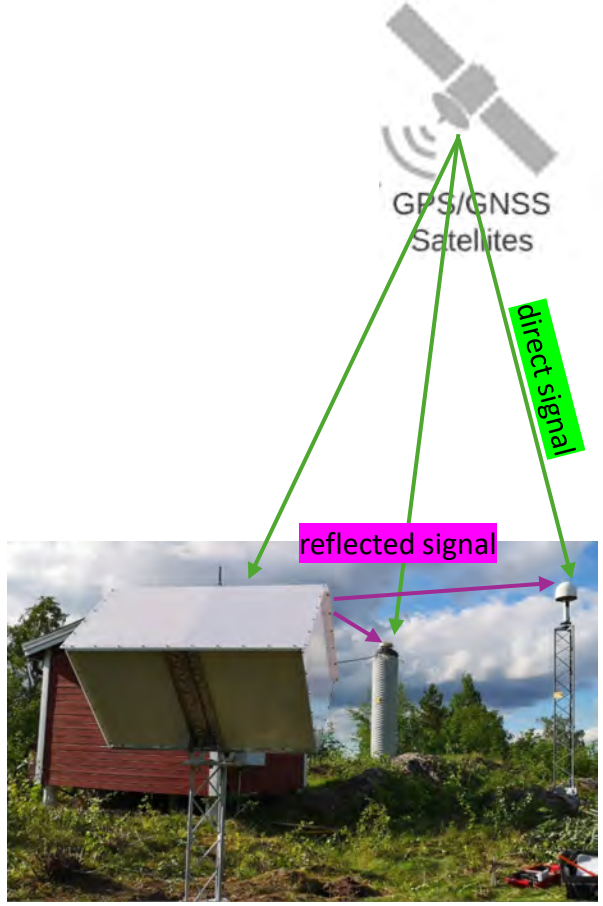
- **3** Transponders and **20** passive corner reflectors installed, **co-located with fundamental GNSS stations.**
- **Main Purpose**: Development and maintenance of geodetic infrastructure in Sweden (Using InSAR technique)
- **Different types of passive corner reflectors** were designed and tested.
- **Getting permission** (for transponders and generally from landowners), the main problem!
- One more CR in the house for installation in the north, waiting for permissions.
- Data analysis **SNAP + Gecoris, SCT and SARvey (open source)**

No multipath effect on daily coordinates of nearby GNSS stations

No observable disturbance in daily GNSS coordinates before and after CR installation (~6 m separation, different GNSS antenna).



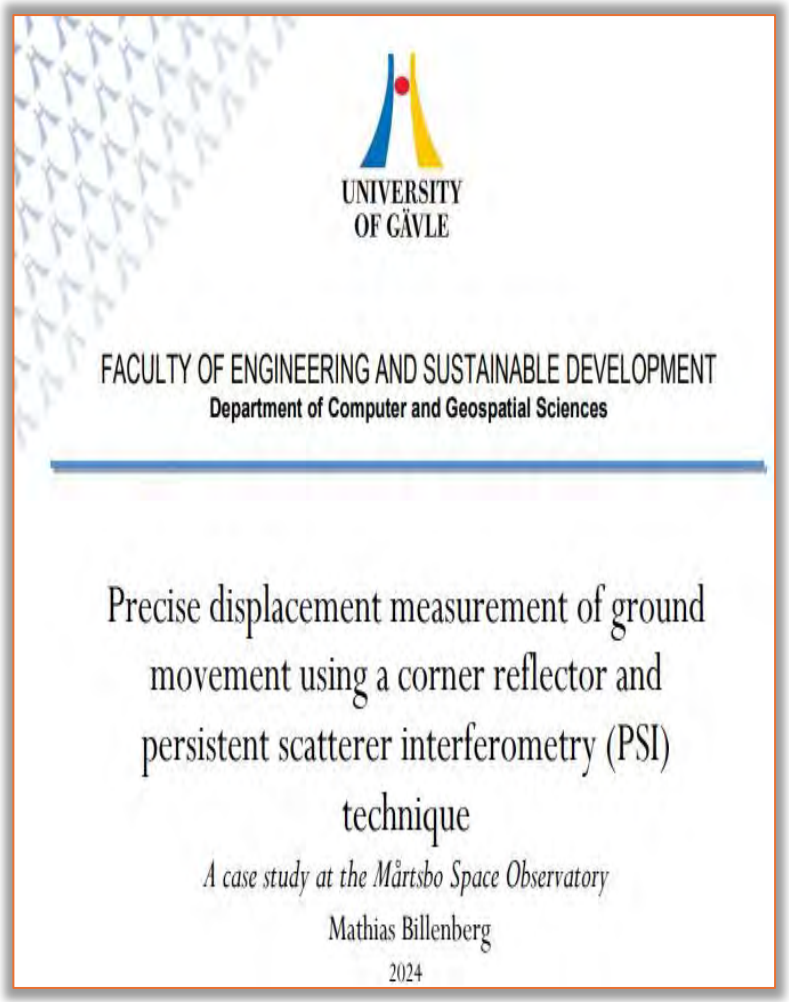




Artificial displacement of a CR (Mårtsbo), Validation experiment

27 Feb 2024, **9-mm** thick disc added

CR displaced only in **vertical** direction!



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Department of Computer and Geospatial Sciences

Precise displacement measurement of ground movement using a corner reflector and persistent scatterer interferometry (PSI) technique

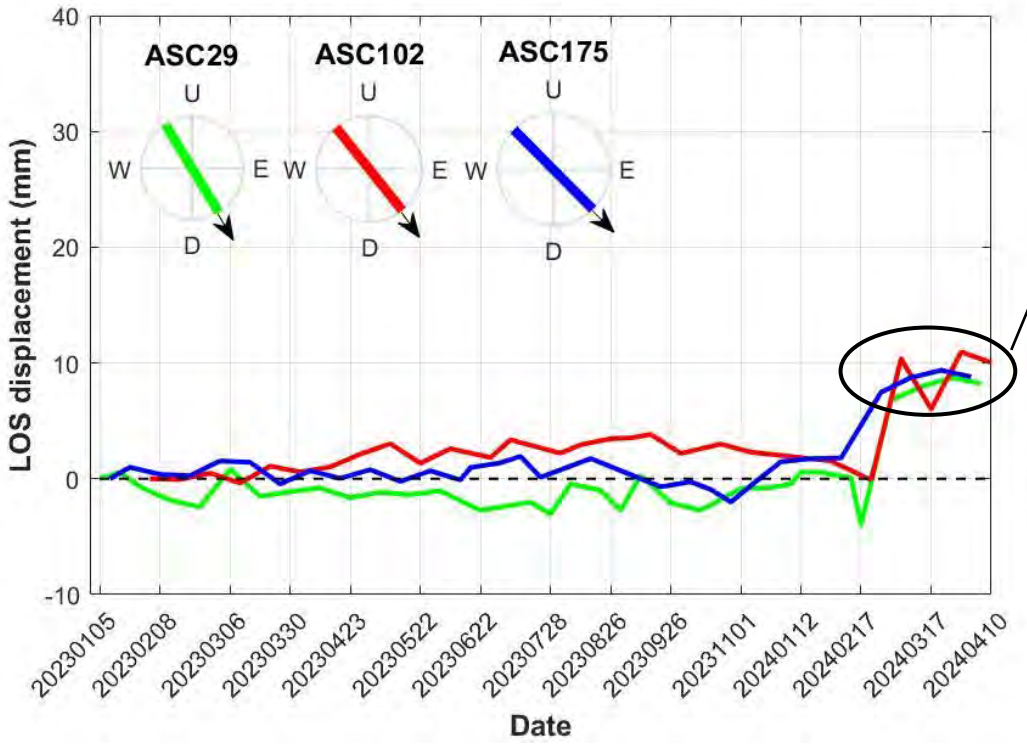
A case study at the Mårtsbo Space Observatory

Mathias Billenberg

2024

https://hig.diva-portal.org/smash/record.jsf?pid=diva2%3A1888368&dswid=-1762

LOS displacements (before and after Disc addition)



A few images after disc addition, still could show the shift (jump), clearly in the time serries ±2 mm

LOS to vertical displacements

$$d_{\mathrm{LOS}} = d_v \cos\theta - d_e \cos\phi \sin\theta + d_n \sin\phi \sin\theta$$

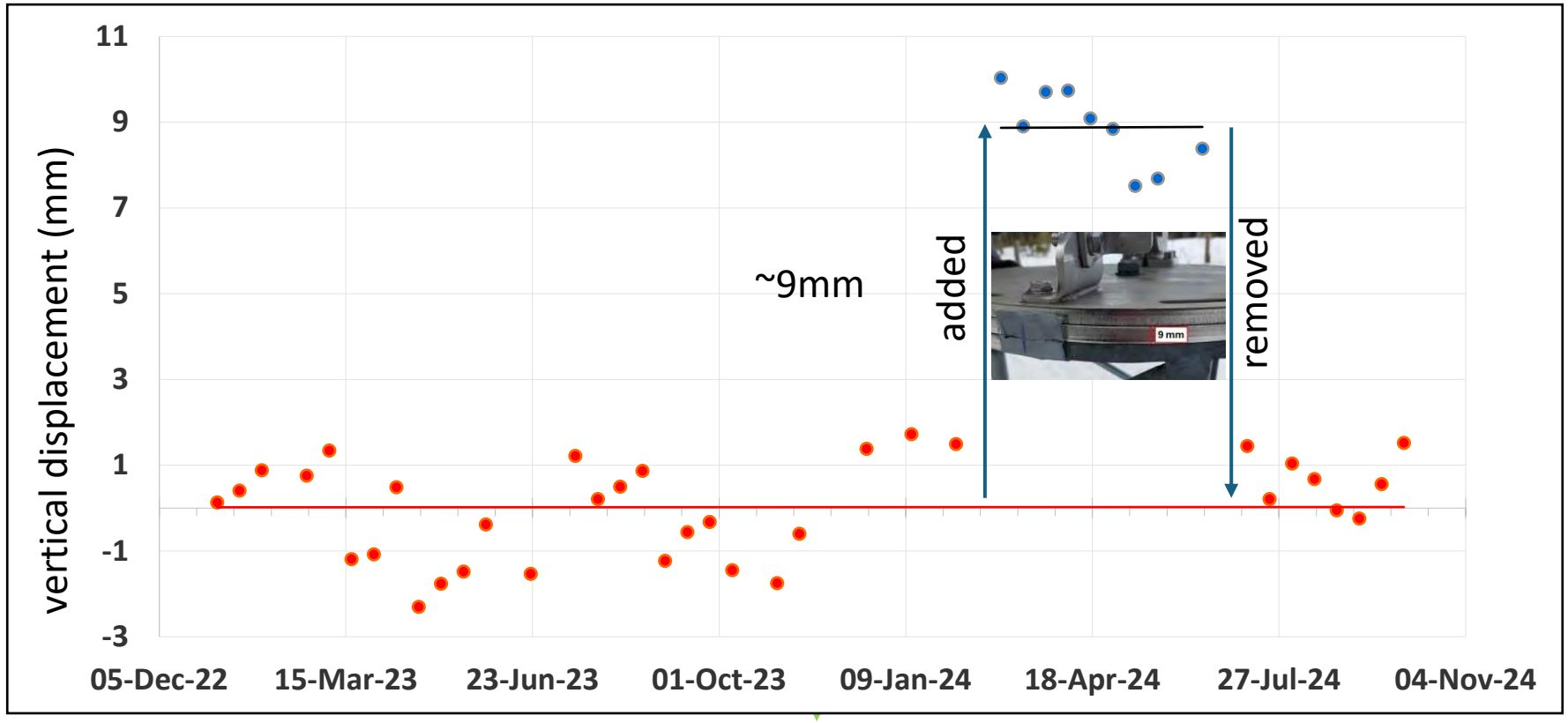
- d_{LOS}: Displacement observed along the satellite's line of sight.
- d_v: Vertical displacement.
- d_e: Eastward displacement.
- d_n: Northward displacement.
- θ: Incidence angle, which represents how tilted the satellite's view is from vertical.
- ϕ: Azimuth angle, which represents the direction the satellite is looking relative to north.

Data processed with both Gecoris and SARPROZ software.

No horizontal movements → $d_v = \dfrac{d_{\mathrm{LOS}}}{\cos\theta}$

New processing: Disc addition and removal

- **Two** artificial displacements of the CR: adding **and removing** of the 9 mm thick disc!
- New data processing, (Asc 29), using PSI and Gecoris toolbox
- ***PSI analysis results detected two ~9 mm artificial displacements of the CR precisely.***



27 Feb 2024 disc added
10 July 2024 disc removed

Snow effect on Radar cross section (passive corner reflectors)

- Two corner reflectors at same site, ~100 m apart, one with cover and one without
- RCS drop is corelated with the snow inside and above the CR protection cover, wind and temperature.

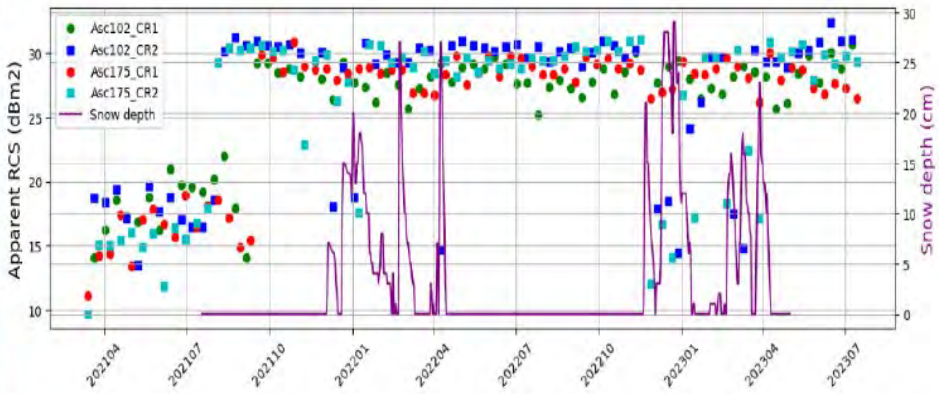


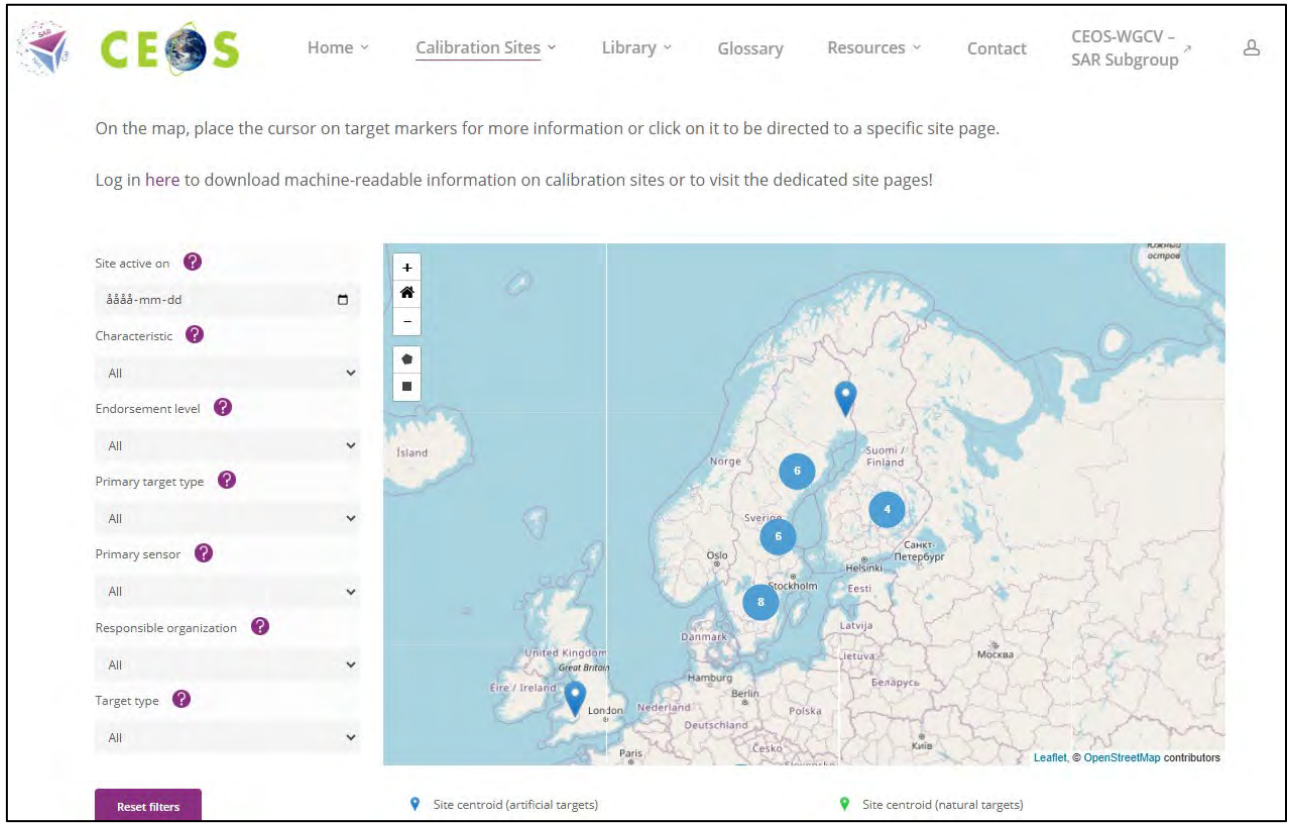
Figure 4: Two CRs in Mårtsbo test field, one (CR1) well mounted with snow cover and one (CR2) on the ground without cover. During the snow season, the difference between two CRs is observed in the apparent RCS time serries. We did also RCS_vs_Snow_depth time serries for other stations for example (Östersund, Umeå and Skellefteå) which have different shape and size. As we can see below, depends on location, they behave differently in wintertime.

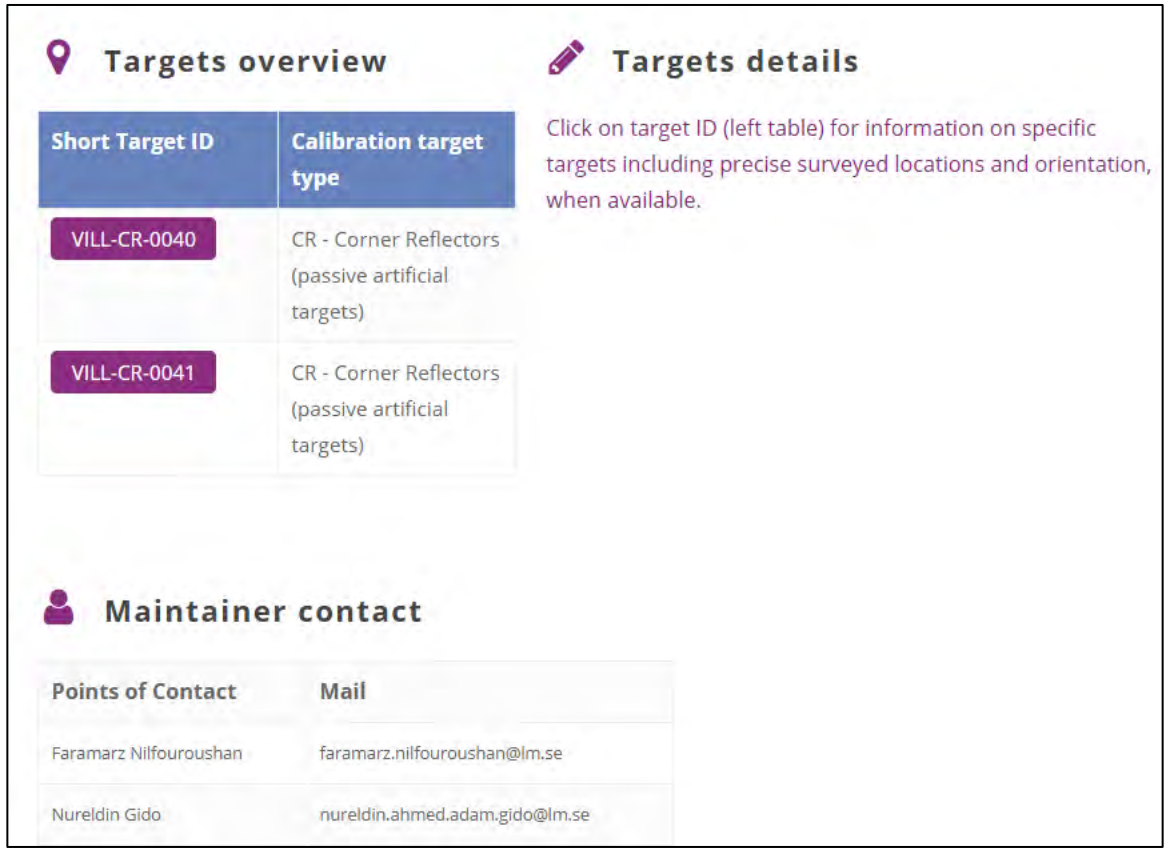
Vilhelmina: CR+ 2 GNSS (time-lapse).

CR has snow cover protection. Co-located GNSS stations are equipped with radome heaters.

Our CRs and transponders visible in SAR Calibration/Validation database

CEOS-WGCV - SAR Subgroup
The Committee on Earth Observation Satellites
Working Group on Calibration and Validation
Synthetic Aperture Radar Subgroup





https://www.sarcalnet.org/

Summary & take-home messages

- Sweden now has a network of passive corner reflectors and active transponders, forming **a geodetic backbone** for SAR/InSAR and geodetic applications.
- Collocated **GNSS–CR** sites provide stable, long-term reference points for InSAR calibration, cross-validation, and atmospheric correction assessment.
- Controlled experiments (*e.g., 9 mm artificial displacement*) **demonstrate millimeter-level detection capability**.
- Snow effects, significantly influence radar backscatter , highlighting the importance of protective design and seasonal evaluation.
- **Integration with SARCalNet** ensures **international visibility for Cal/Val activities.**

Next steps: we continue data processing, time-series analyses and cross validations of GNSS and CRs and Contribute to European harmonization of **Cal/Val practices**.

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Thank you for your attention!

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Installation of corner reflectors close to GNSS stations (Visby, May 2022)