SAR reflektorer och deras tillämpningar i geodetisk infrastruktur: en lägesrapport om installation av passiva reflektorer i Sverige

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April 18, 2023

UNIVERSITY OF GÄVLE

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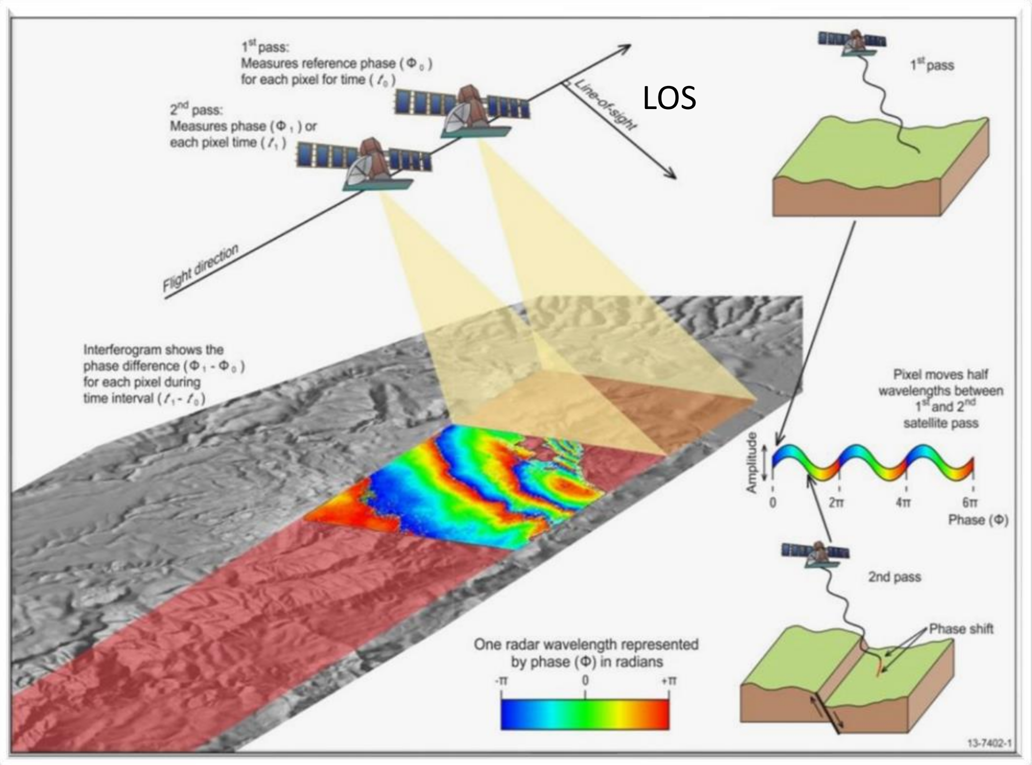
InSAR (Interferometric Synthetic Aperture Radar)

SAR is an **active radar** system; no limitation with clouds, day and night system

The reflected signal is responsive **to surface characteristics like structure and moisture.**

-**InSAR** uses several radar images and correlate them for DEM generation and/or **ground motion measurements (DInSAR, PSI, …)**

Relative motion!



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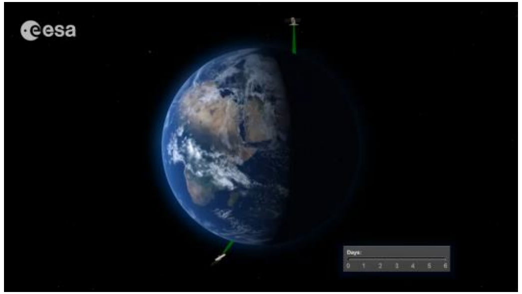
InSAR Potential

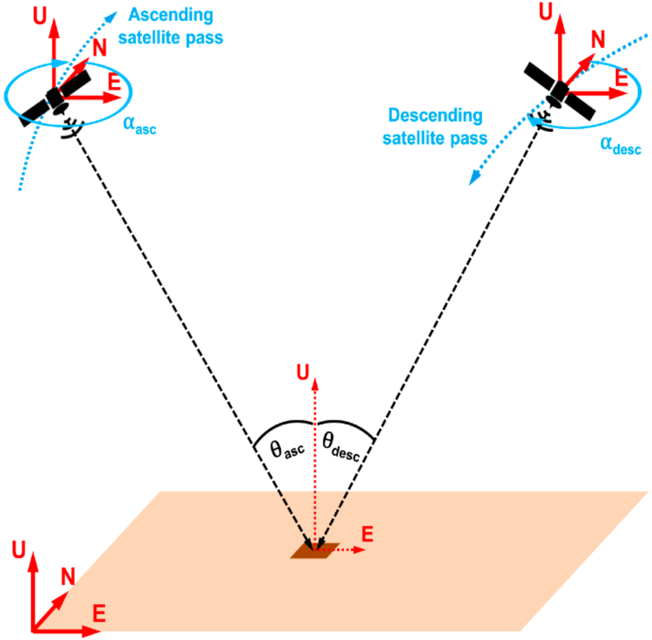
Advantages

- Monitoring of large area with **Copernicus Sentinel-1** **(**spatial resolution 5X20 m)
- High acquisition frequency (**Sentinel-1A, 12 days**)
- High spatial sampling
- Generating time series (**spatio-temporal deformation**)
- Free of charge archived data (ERS1, ERS2, …, Sentinel-1)

Limitations:

- Land cover limitations (vegetations, wetlands, …)
- Snow season
- **LOS measurements,** Less sensitive to N-S motion, **mainly vertical and E-W components**





https://www.mdpi.com/2072-4292/11/3/241

InSAR for Geodetic infrastructure

- InSAR can **measure** the ground movements accurately

- More efficient and less expensive stability control of the **geodetic infrastructure** (reference frames, tide gauges, GNSS permanent stations, leveling benchmarks, gravity points)

- Analysis of linear and non-linear movements

- Better understanding of ongoing processes:
  - ➢ Glacial isostatic adjustments (GIA modeling)
  - ➢ Crustal deformations (plate tectonics,…)
  - ➢ Hydrological loading signals

- Coastal erosion studies and better sea level predictions

Lantmäteriet SWEPOS GNSS reference stations

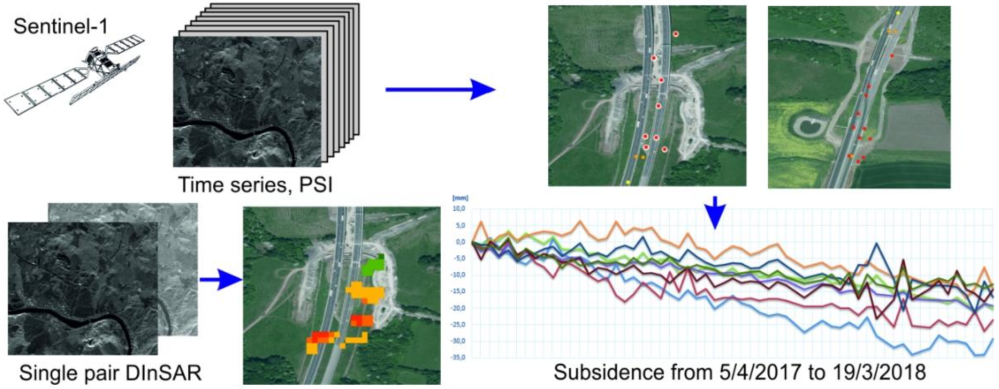
PSInSAR (PSI)

- **Persistent Scatterers Interferometry** uses coherent radar targets (**PS**) that can be **clearly distinguished in all images** and do not vary in their properties.
- The atmospheric and orbital errors are essentially removed.
- Sub-pixel radar reflections are analyzed.
- Linear and non-linear movements are identified.

PS examples: Rocks, buildings, …

- **These coherent radar targets are abundant in urban areas but are very scarce in the vegetated areas.**

Corner reflectors, artificial PS!



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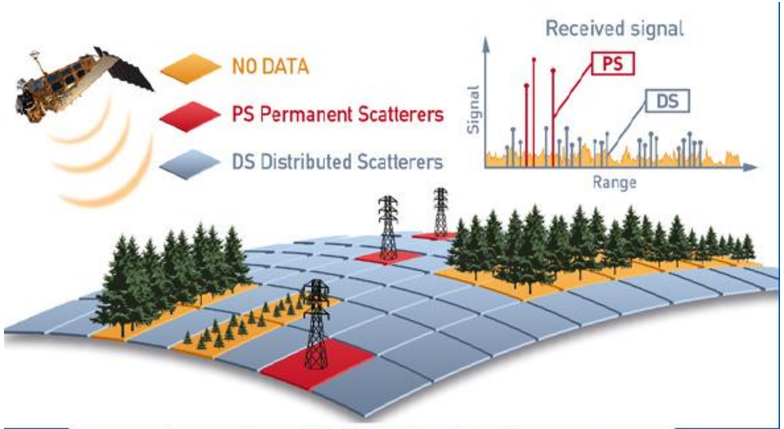
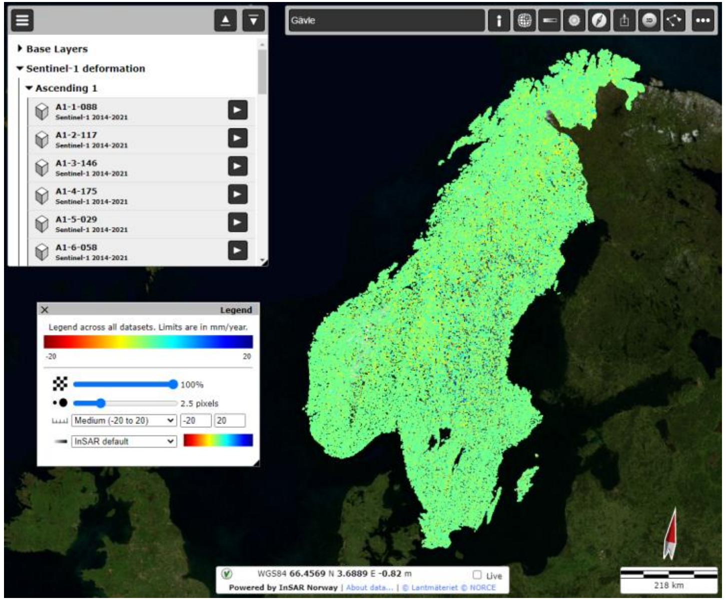


Image from TeleRilevamento Europa

InSAR-based National Ground Motion Service (GMS) of Sweden (InSAR-Sweden)

- **Project started: 2020-10-15, finished: 2022-12-31**
- **GMS of Sweden**, produced by NGU (first did for Norway)
- Based on **PSI** technique using both **ascending and descending Sentinel-1** data (**2015-2021**),
- **>~1500,000,000 PS** points with their time series (**LOS**)



https://insar.rymdstyrelsen.se

LANTMÄTERIET

GEOLOGICAL SURVEY OF NORWAY

SGU Geological Survey of Sweden

Rymdstyrelsen Swedish National Space Agency

TRAFIKVERKET

CHALMERS UNIVERSITY OF TECHNOLOGY

SWEDISH GEOTECHNICAL INSTITUTE

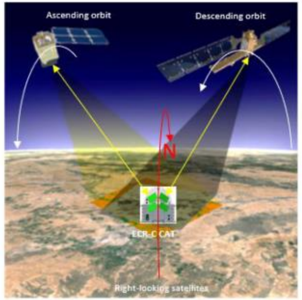
FOI

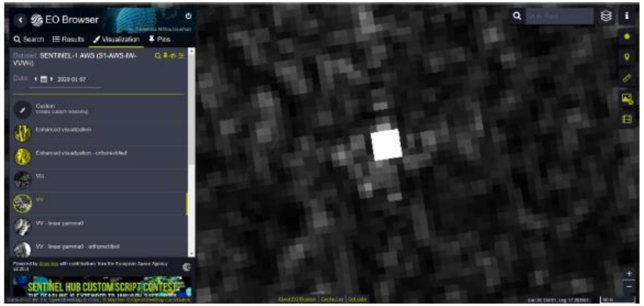
Corner reflectors

Corner reflectors are artificial radar reflectors useful for precise measurements of ground motion at **desired locations.** Two types:

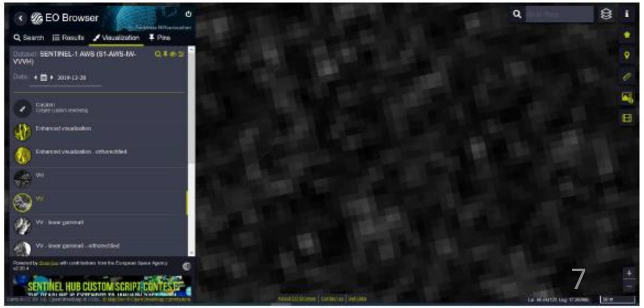
Passive Corner reflectors (no electronics), just made of orthogonal metal plates

Electronic Corner reflectors(ECR) or Transponders, Lantmäteriet has installed 3 ECRs in Kobben, Vinberget and Mårtsbo





S1 image, January 7th, 2020, the first visit of S1 over the station.



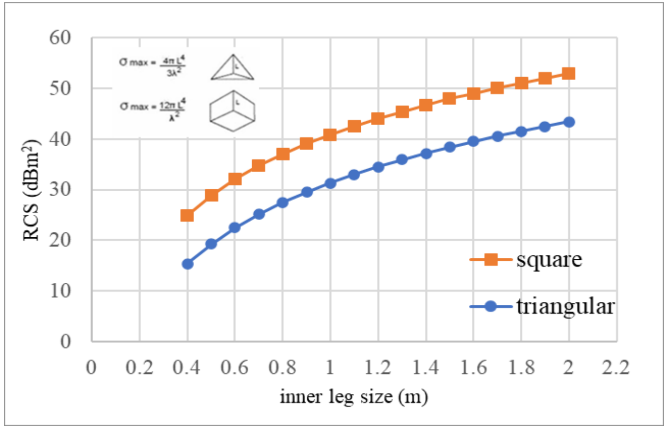
Passive reflectors: RCS and SCR

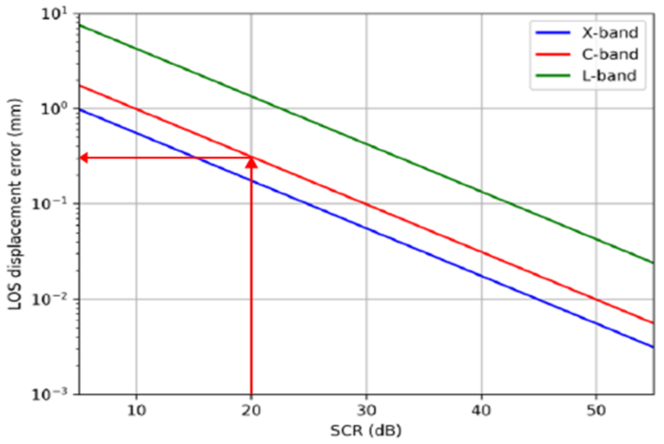
The radar response depends on target size, shape and radar frequency.

The **Radar Cross Section (RCS)** is the ratio of the energy reflected by the target to the SAR sensor and the transmitted energy.

The strength of the signal reflected by CR with respect to its surrounding reflections (**clutter**) can be measured and is called the **Signal-to-Clutter Ratio (SCR)**.

Based on required accuracy and application, the proper CR size and shape is selected

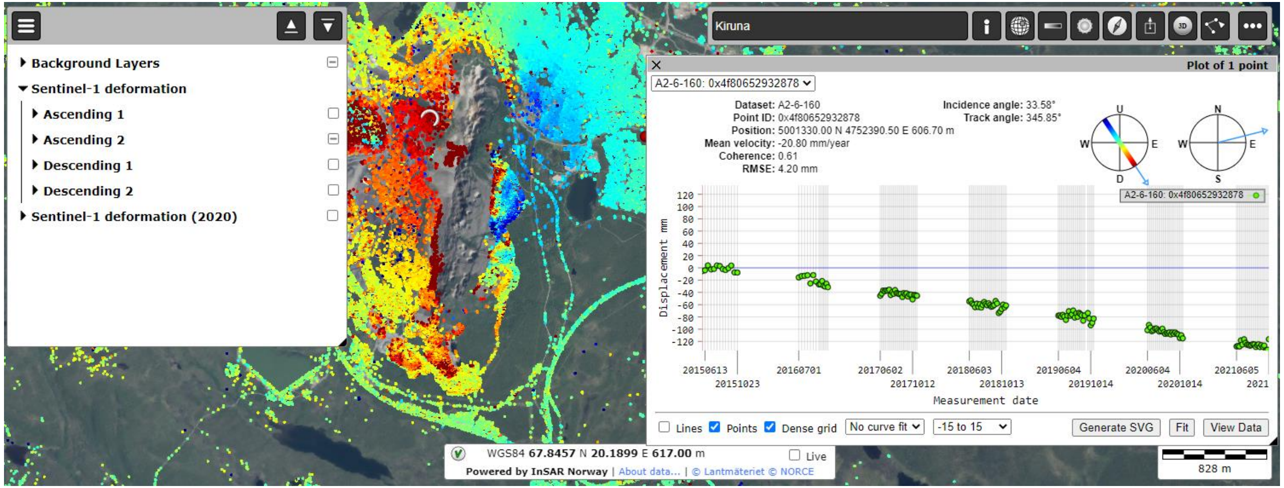


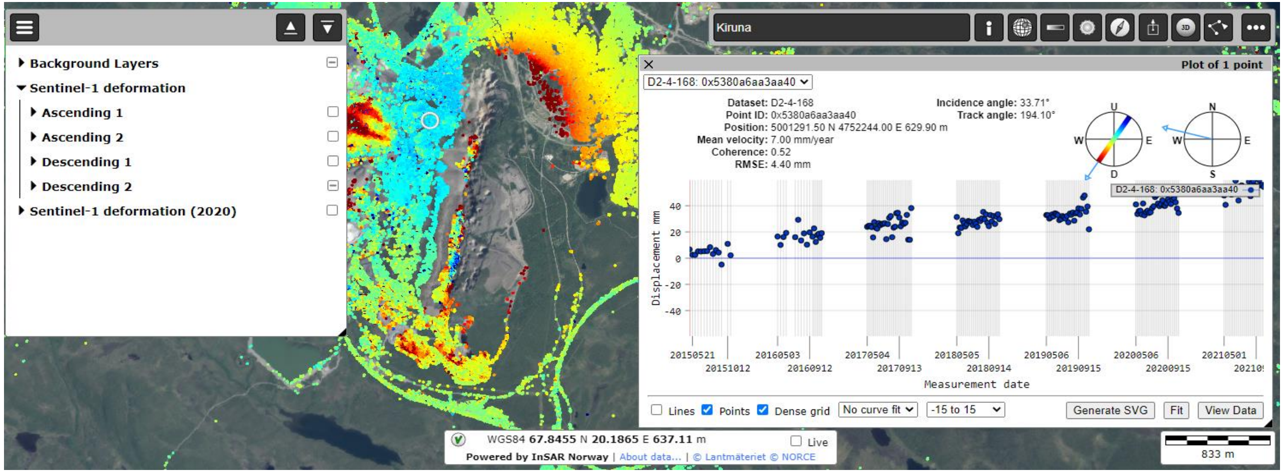


Why using both ascending and descending reflectors?

Descending and Ascending rates, LOS maps

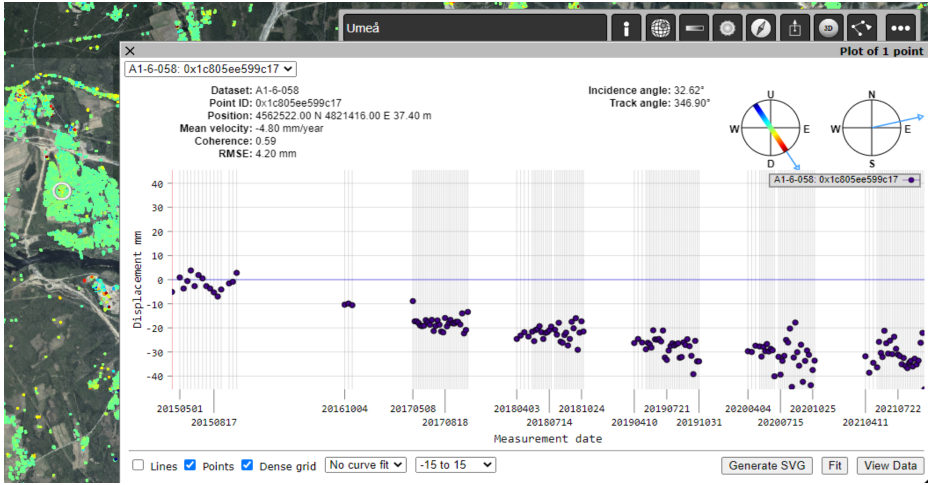
Totally different results for Kiruna, different colors, different movements, EW motions + vertical!



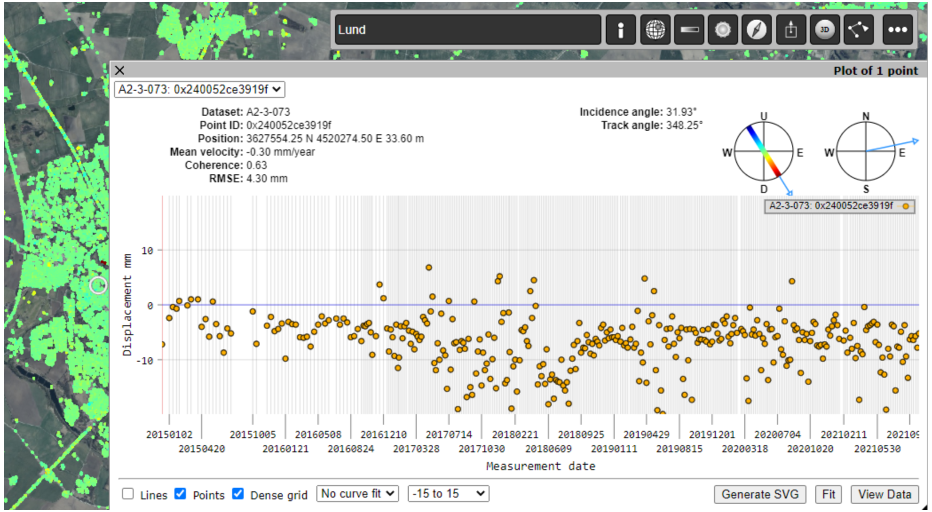


Gaps in the time series of PS points

Umeå, North of Sweden, lots of snow, gaps in the time series



Lund, South of Sweden, dense time series



Corner reflectors help?

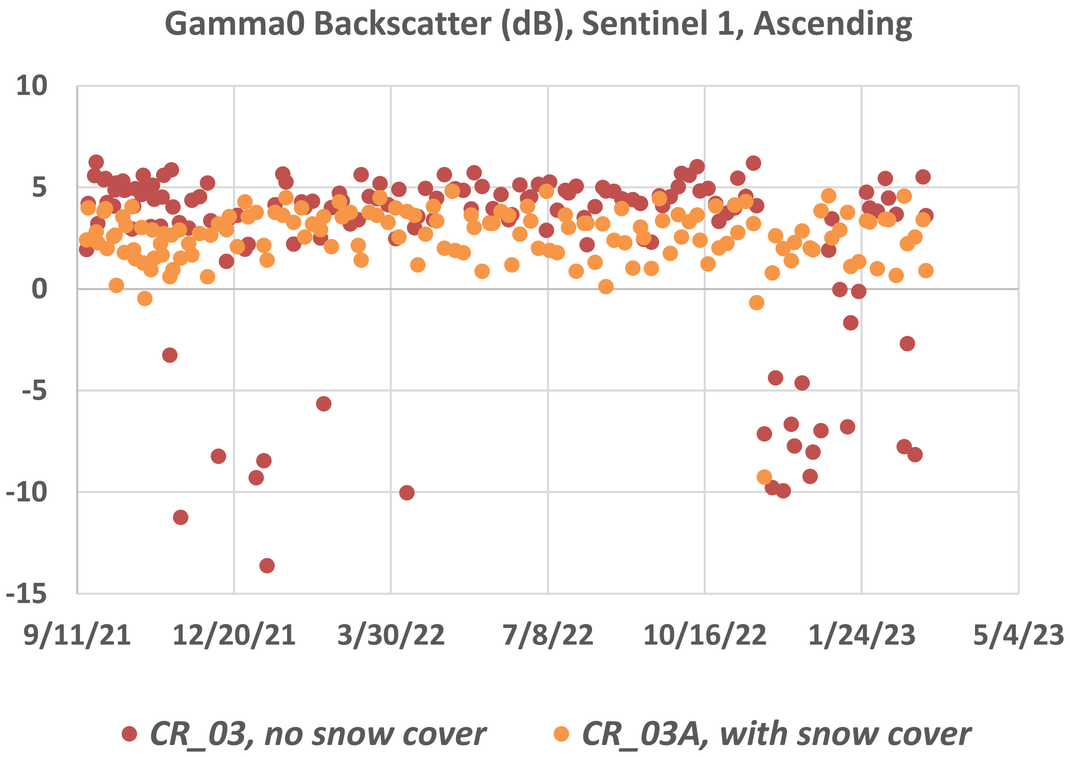
Snow effect on CR backscattering

Two CRs in Mårtsbo, one well mounted with snow cover and one on the ground without cover!

CR03

CR03A

Photos taken on 27 Dec. 2022



Gaps in time serries in wintertime!

Establishment of a CR infrastructure in Sweden

- There are **21** class A permanent GNSS stations with inter spacing around **250 km, suggested** for CR locations

- Co-located stations: the **time series and velocities** of GNSS and CRs can be compared and help for analysis. In case of co-location with tide-gagues, helps vertical land motion monitoring.

- Potentially useful for **calibration of Swedish GMS and European GMS (EGMS); transforming to a well-defined geodetic ref. frame**

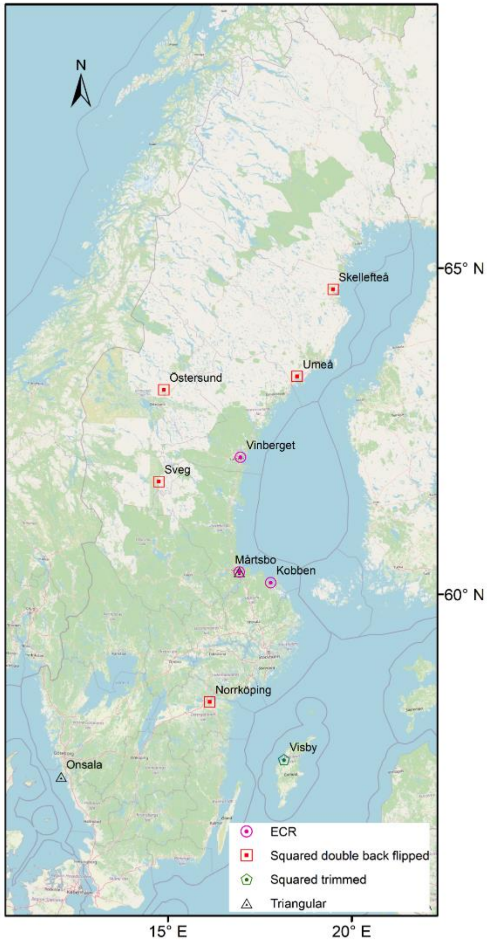
- **Better georeferencing of PS points**

CR/ECR installations

3 ECRS and 10 CRs (different type and size) installed in 11 locations, 11 more CRs to be installed this year

Table 3, Installed corner reflectors and transponders in different locations in Sweden (coordinates are in SWEREF 99 reference frame)

ID	Latitude	Longitude	Location	Passive/Active	Date of Installation	Type	Orientation
ECR01	60.5951	17.2585	Mårtsbo	Active	2020-01-07	Electronic transponder	Asc and Desc
ECR02	60.4099	18.2303	Kobben	Active	2020-06-01	Electronic transponder	Asc and Desc
ECR03	62.3739	17.4279	Vinberget	Active	2020-10-01	Electronic transponder	Asc and Desc
CR01	57.3949	11.9220	Onsala	Passive	2021-06-01	Triangular	Asc
CR02	57.3950	11.9222	Onsala	Passive	2021-09-10	Triangular	Desc
CR03	60.5946	17.2596	Mårtsbo	Passive	2021-09-14	Triangular	Asc
CR04	58.5900	16.2451	Norrköping	Passive	2021-11-04	Double back flipped squared	Asc and Desc
CR05	57.6540	18.3671	Visby	Passive	2022-05-11	Squared trimmed	Desc
CR06	57.6540	18.3671	Visby	Passive	2022-05-11	Squared trimmed	Asc
CR07	62.0173	14.7000	Sveg	Passive	2022-06-14	Double back flipped squared	Asc and Desc
CR08	63.4427	14.8579	Östersund	Passive	2022-09-01	Double back flipped squared	Asc and Desc
CR09	63.5781	19.5096	Umeå	Passive	2022-10-21	Double back flipped squared	Asc and Desc
CR10	64.8792	21.0485	Skellefteå	Passive	2022-10-23	Double back flipped squared	Asc and Desc

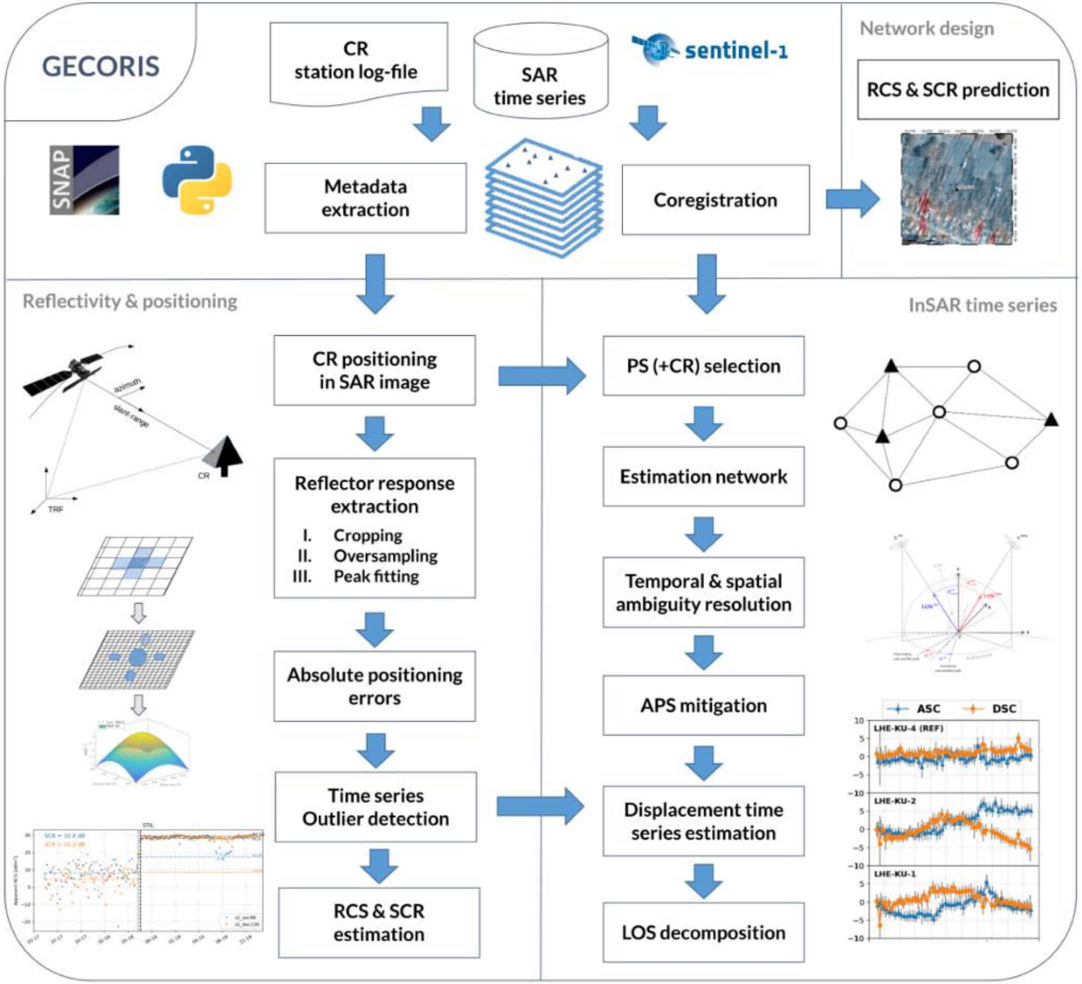


Many challenges: Suitable location for CR, permissions, contracts, easy access, …

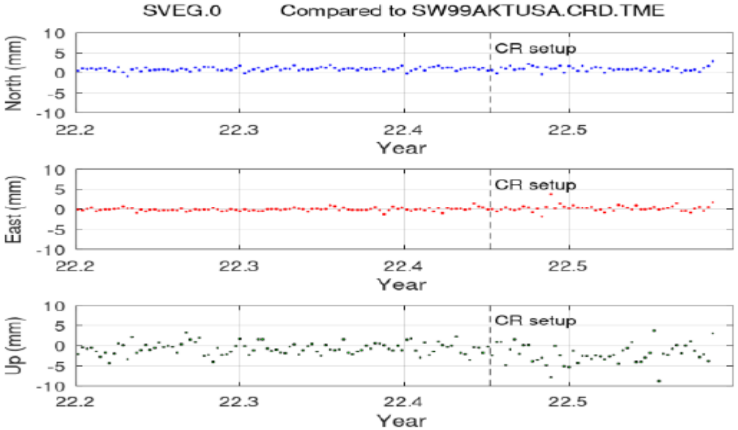
Data analysis

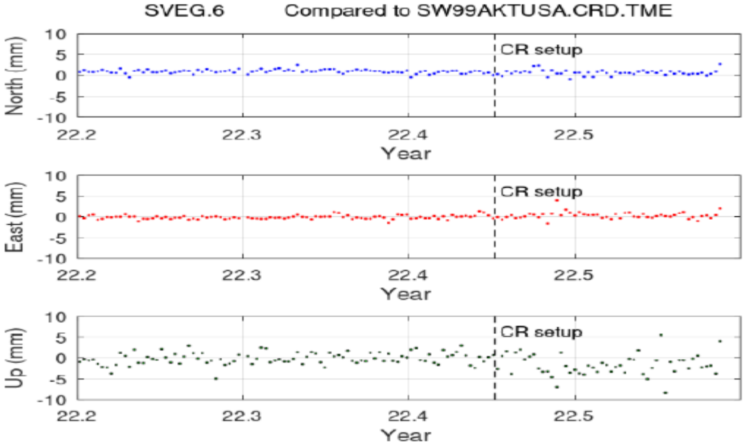
- GECORIS and SNAP software
- Sentinel-1 ascending and descending SAR data
- RCS and SCR analysis (performance of CRs)
- PSI (deformation analysis)

Czikhardt et al., 2021, GECORIS: An Open-Source Toolbox for Analyzing Time Series of Corner Reflectors in InSAR Geodesy. Remote Sensing. 2021; 13(5):926.



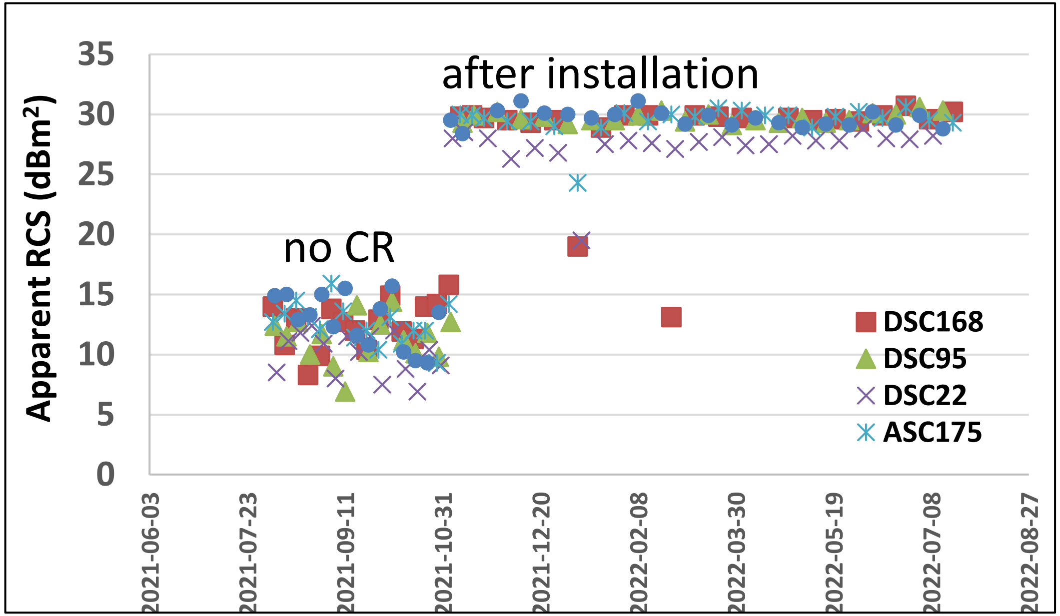
No significant multipath effect on nearby GNSS stations

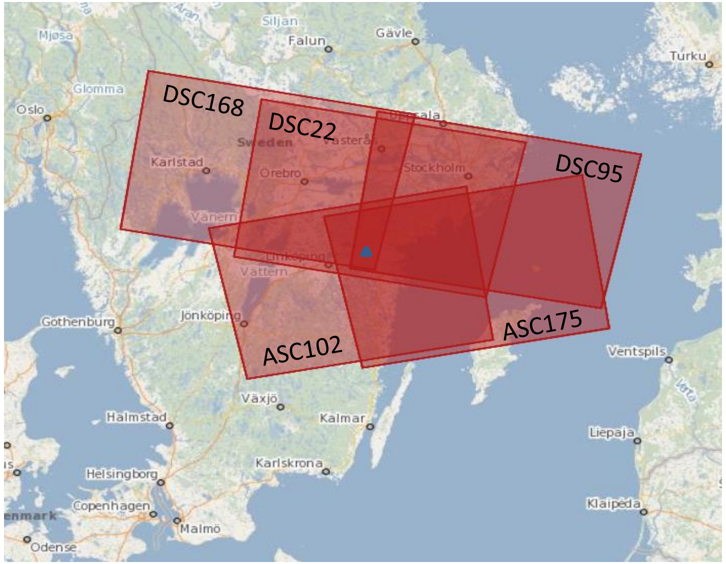




*Daily GNSS coordinate time series (**SVEG 0 and SVEG 6**) before and after CR installation, double back flipped squared CR is ~6 m away from the mast station. The time series show daily residuals relative to the official SWEREFF 99 coordinates of each station.*

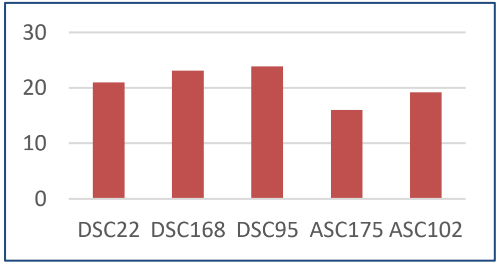
Data analysis, RCS and SCR for CR at Norrköping airport





For Sentinel-1, C-band:

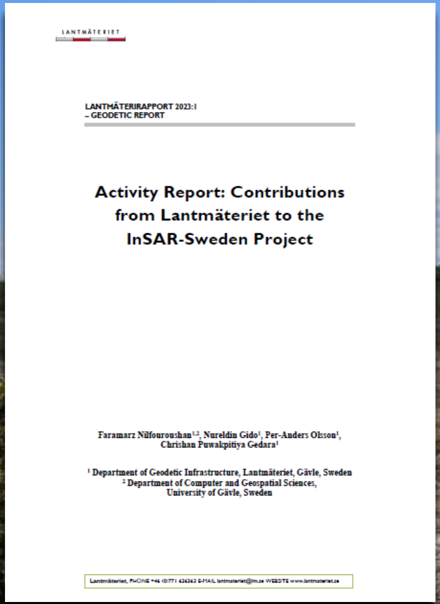
if SCR ~20 dB → LOS displacement error = ~0.5 mm.



Conclusions/Take home messages

- InSAR is a remote sensing/geodetic technique, based on analysis of radar images taken in different time
- InSAR has great potential to **localize and measure the ground motion** with mm accuracy.
- A new geodetic infrastructure is built up by Lantmäteriet using **corner reflectors.**
- These reflectors are co-located with SWEPOS GNSS stations and help better analyzing the coordinates and velocities.
- The first results (RCS and SCR) obtained from existing CRs are promising. Work is in progress!

Thank you for your attention!



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LANTMÄTERIRAPPORT 2023:1
– GEODETIC REPORT

Activity Report: Contributions from Lantmäteriet to the InSAR-Sweden Project

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Radra twin corner reflectors and twin GNSS stations, Visby