SAR Imaging Geodesy with Electronic Corner Reflectors (ECR) and Sentinel-1

First Experiences

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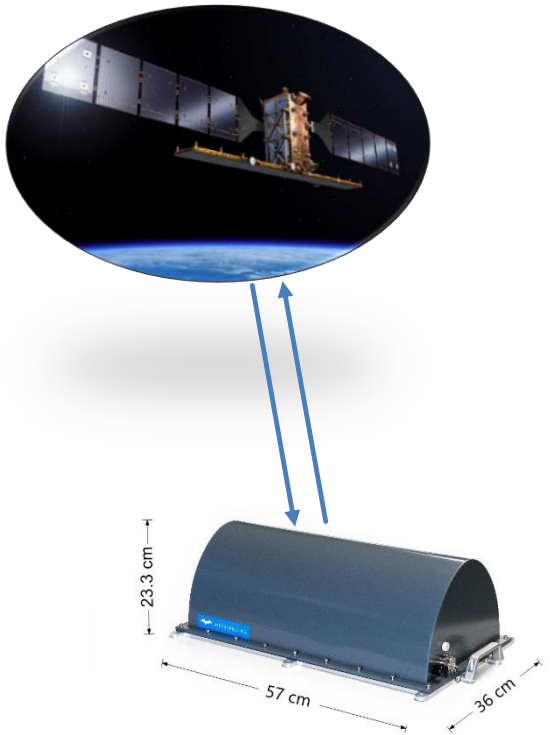
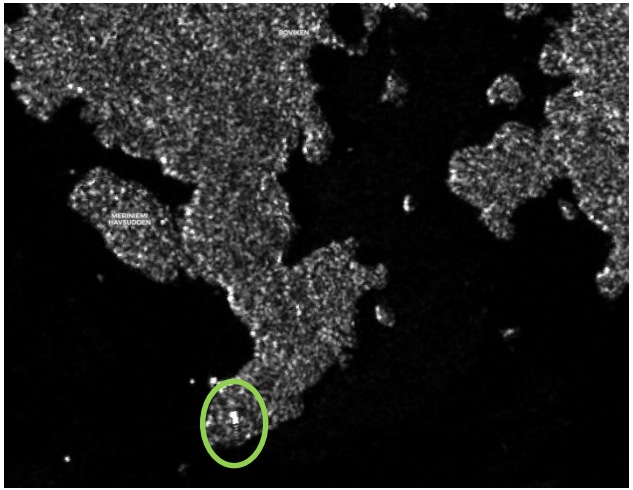
The instrument: ECR-C



MetaSensing ECR-C

- The Electronic Corner Reflector (ECR) is a small active instrument that can be used as a ground **radar target**.
- It is also known as '**transponder**' or **CAT** (compact active transponder).
- The ECR **collects** the signal from a passing radar satellite, **amplifies** it and **re-transmits** it.
- The ECR-C (currently the only ECR available on the market) is frequency-compatible with satellites operating in **C-band** i.e. Sentinel 1A, 1B and RADARSAT-2.

The instrument: ECR-C

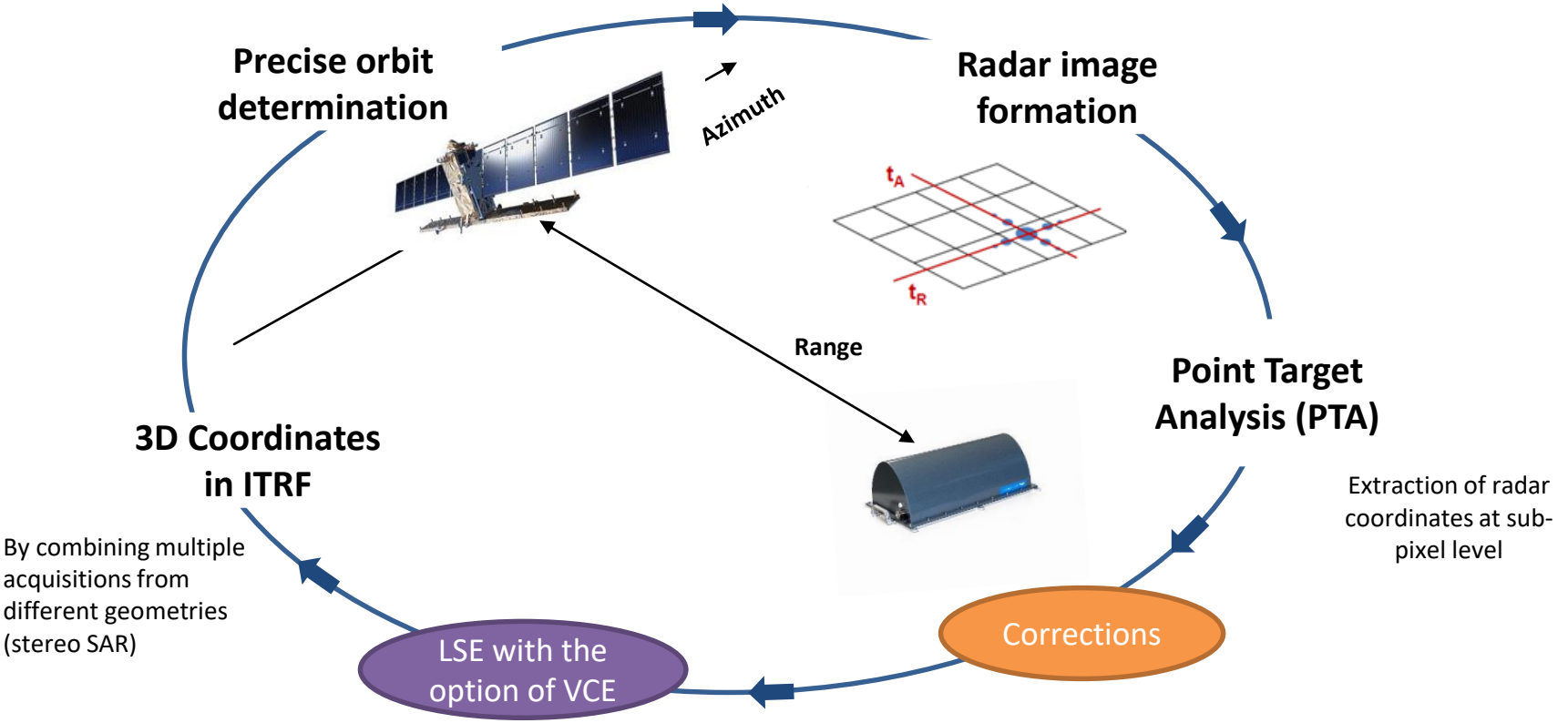


Signature of an ECR installed at Emäsalo, Finland. Sentinel image: GRD, VV-orthorectified. Acquisition: 5, May 2020. Visualization: Sentinel-hub EO-Browser

- The ECR appears as a bright point in a radar image.
- It can be used as a small and compact alternative to passive instruments e.g. trihedral corner reflectors.

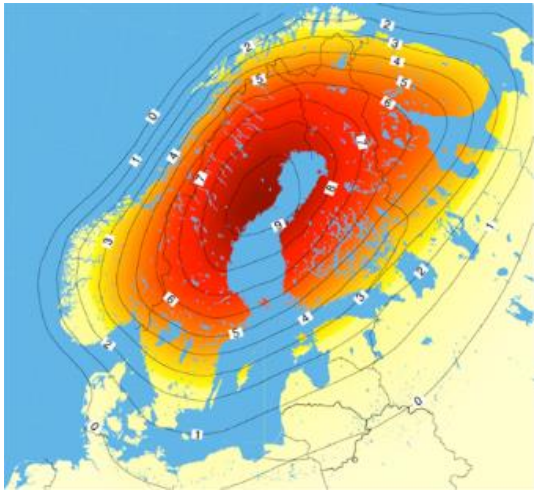
	ECR	Corner Reflector
Tracking of ascending & descending passes	✓	✗
Portability	✓	✗
Power independency	✗	✓

The technique: SAR imaging geodesy with Sentinel-1 and ECR-C



Applications in Geodesy

- Displacement monitoring
- Land uplift
- Height change monitoring
- Height system unification
- Sea level studies



Fennoscandian Land uplift (mm/yr) relative to the centre of the Earth. National Land Survey of Finland. [https://www.maanmittauslaitos.fi/en/research/interesting-topics/land-uplift]

Applications: The ESA SAR Baltic+ Project

Sites on which ECR-Cs have been installed or are planned to be installed in the frame of the ESA SAR Baltic+ Project

- **Project Goal**

  Baltic Height System Unification and Sea Level Research

  - Installation of ECRs at tide gauge stations or at collocation sites with local ties to a tide gauge and/or a GNSS station.
  - Determination of relative vertical motion and correction of tide gauge readings.
  - Unification of height systems of Baltic countries.

✓ Supporting ECR and CR stations at Metsähovi, Finland, DLR Oberpfaffenhofen, Germany and Wettzell, Germany

ECR-C Installation, Mounting & Operation

Installation

- **Transmitting license** required in order to operate an ECR (active instrument).
- **Power support** required for continuous operation (longer than 1-2 weeks). The main battery can be recharged via AC or solar panels.

Mounting

- **Supportive structure** required for a successful installation. Solutions include: Concrete base/pillar, aluminum mast etc.
- The ECR must be **oriented** towards the geographic north to properly cover for both ascending and descending orbits.

Example of a mounting structure at Loksa, Estonia. Courtesy of Tallinn University of Technology

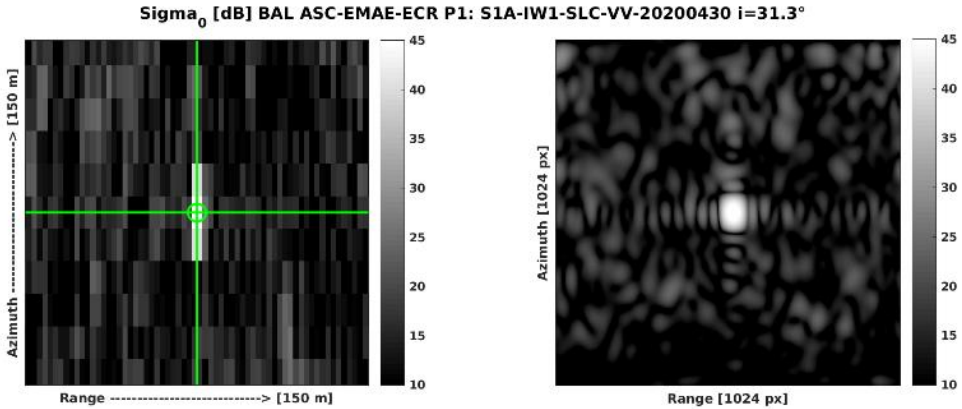
System Operation

- Activations can be programmed via a dedicated **GUI**.
- Past activations and system details (internal temperature, power etc.) are available in log files.

Early Results – Emäsalo, Finland

1. Image Analysis

✓ RCS value of ~ 42 dBm^2



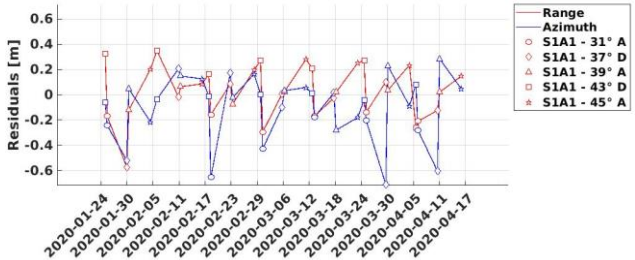
Emäsalo ECR RCS as derived from Sentinel-1A radar images.

2. Corrections

- ✓ Geodynamic
- ✓ Troposphere
- ✓ Ionosphere

Early Results – Emäsalo, Finland

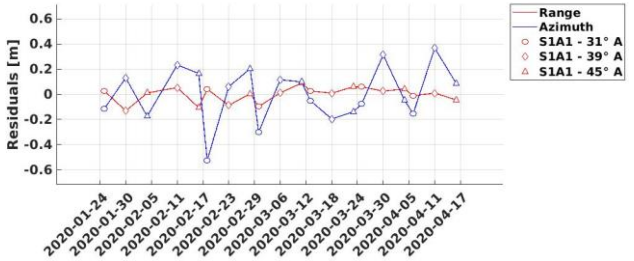
3. Positioning - period 25 January – 16 April 2020



- **20** acquisitions from **Ascending** node
- **14** acquisitions from **Descending** node

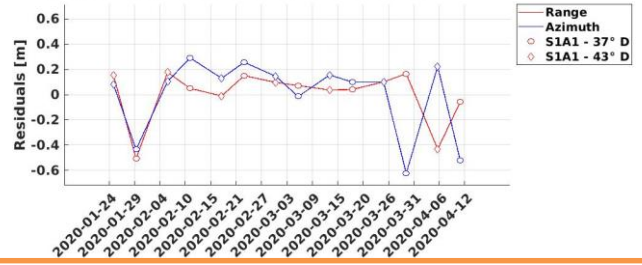
Positioning Accuracies

σx [+-m]	σy [+-m]	σz [+-m]
0.0441	0.0563	0.0491



- **20** acquisitions from **Ascending** node

σx [+-m]	σy [+-m]	σz [+-m]
0.0414	0.1129	0.0900



- **14** acquisitions from **Descending** node

σx [+-m]	σy [+-m]	σz [+-m]
0.5257	0.6153	0.6438

First Impressions

- **Radar Cross Section** at approximately 40 dBm^2, corresponding to a 1.8 m Corner Reflector.
- ECR signature **easily recognizable**, even within areas with some background noise.
- Updates in the ECR GUI and user manual are expected to **resolve operability issues** encountered with some instruments during testing.
- Early testing (2.5 months of data acquisition) suggests positioning accuracies of around **5-6 cm**.
- Acquisitions between ascending and descending passes might be subject to biases.

Next steps

- Completion of the **ECR network** around the Baltic.
- Correction for ECR internal **delays**.
- Identification and removal of possible ECR **system-related outliers**.
- Improvement of the **precise orbit handling**.
- **Extension** of the acquisition period.
- Assessment of the data period impact on the positioning accuracy.

Conclusion

- The ECR-C is an **active instrument**, compatible with radar satellites operating in **C-Band**, such as **Sentinel-1**.
- It can be used as an **alternative to passive instruments** like Corner Reflectors, which are typically quite large and difficult to transport.
- The **3D coordinates** of an installed ECR-C can be determined on the principle of **SAR imaging geodesy**.
- **Early results** with Sentinel-1A suggest positioning **accuracies** of about **5-6 centimetres**.
- **Improvements are expected** when data from more months are acquired, system-related outliers are removed and internal delays or biases are considered.

References and Acknowledgments

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