Geodetic SAR – the use of electronic corner reflectors in Władysławowo and Łeba, Poland

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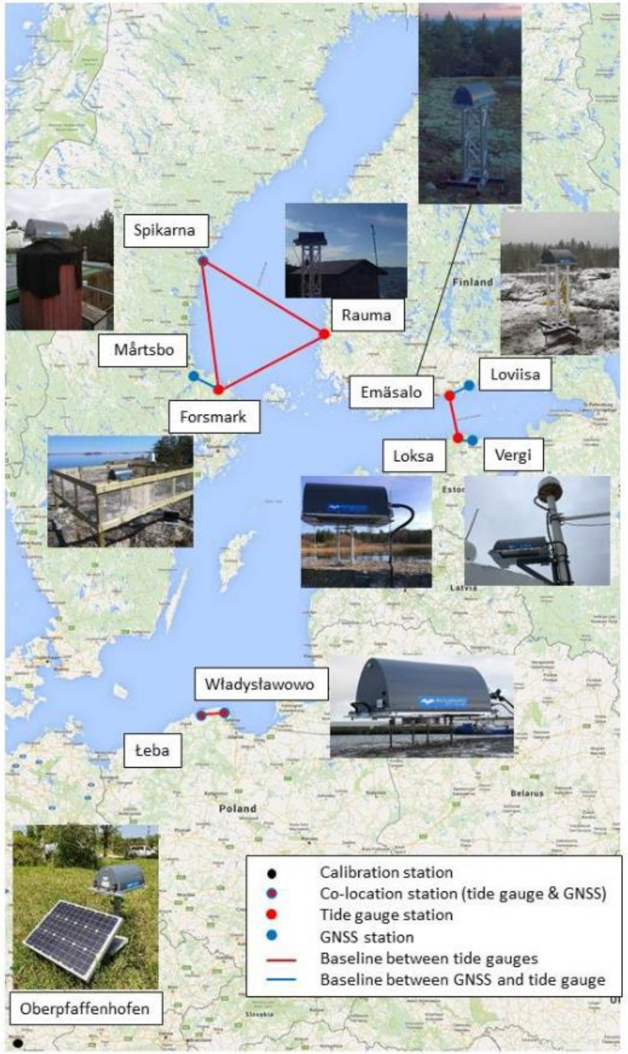
Geodetic SAR - motivation



ECR sites. Map source: Gruber et al. (2020)

Geodetic SAR was used in research conducted in 2019-2021 in the European Space Agency project **„Geodetic SAR for Baltic Height System Unification"** (details in Gruber et al., 2020). Electronic corner reflectors (ECR) were used as targets for Sentinel-1 satellites.

Regardless of the project, independent software for geodetic SAR processing is currently being developed at CBK PAN since August 2020 with great support of Christoph Gisinger (DLR). Software helps CBK PAN to study the behavior of the ECR on Polish sites in Władysławowo (WLAD) and in Łeba (LEBA) after the end of the project.

Software consists of:

- Data collection and preparation modules (including SAR data, EOP, precise orbits, ionosphere and troposphere models);
- Processing module related to geodynamic effects and corrections to radar measurements;
- Module for preliminary analysis of results (reports, charts).

Software still needs some final tuning for better performance.

Electronic corner reflector in Władysławowo, Poland (WLAD) (photo by R. Zdunek)

Electronic corner reflector in Łeba, Poland (LEBA) (photo by R. Zdunek)

Thomas Gruber, Jonas Ågren, Detlef Angermann, Artu Ellmann, Andreas Engfeldt, Christoph Gisinger, Leszek Jaworski, Simo Marila, Jolanta Nastula, Faramarz Nilfouroushan, Xanthi Oikonomidou, Markku Poutanen, Timo Saari, Marius Schlaak, Anna Świątek, Sander Varbla, and Ryszard Zdunek. 2020. "Geodetic SAR for Height System Unification and Sea Level Research—Observation Concept and Preliminary Results in the Baltic Sea" *Remote Sensing* 12, no. 22: 3747. https://doi.org/10.3390/rs12223747

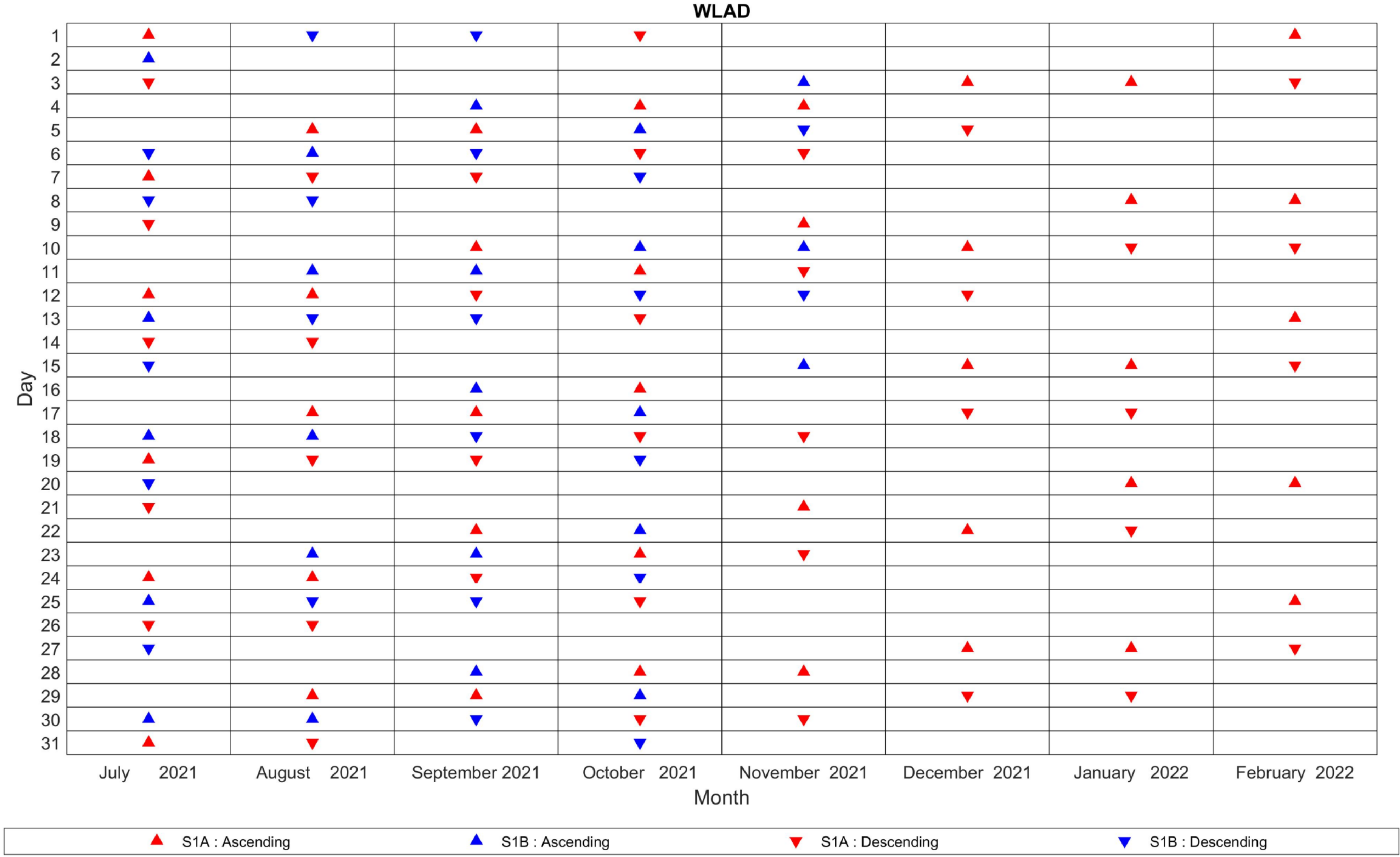
Effects, corrections and background models

Geodynamics	
Secular Trends	ITRF2014 stations combined with MORVEL56 model
Solid Earth Tides	Based on IERS Conventions (2010) and implementations: *dehanttideinelMJD*.f by Véronique Dehant and solid.for by Dennis Milbert
Ocean Loading	Tidal parameters from Chalmers University of Technology http://holt.oso.chalmers.se/loading/ for FES2004 based on IERS Conventions (2010)
Atmospheric Tidal Loading	GSFC VLBI group (Petrol & Boy, 2004)
Pole Tides	IERS Conventions (2010) with use of C04 14
Ocean Pole Tide Loading	IERS Conventions (2010) with use of C04 14 and Ocean Pole Load Tide Deformation Parameters from Self-Consistent Equilibrium Model of Ocean Pole Tide (Desai, 2002)
Precise Orbits	Precise ephemerides from https://scihub.copernicus.eu/gnss/#/home

SAR	
Bulk azimuth correction (azimuth correction)	Based on Sentinel-1 image annotation files
Shift to pulse transmit time (azimuth correction)	
Satellite motion (azimuth correction)	
Azimuth corrections for topography induced FM-rate mismatch (azimuth correction)	
Range correction w.r.t. Doppler (range correction)	
Tropospheric delays (range correction)	Vienna Mapping Function (VMF1)
Ionospheric delays (range correction)	CODE

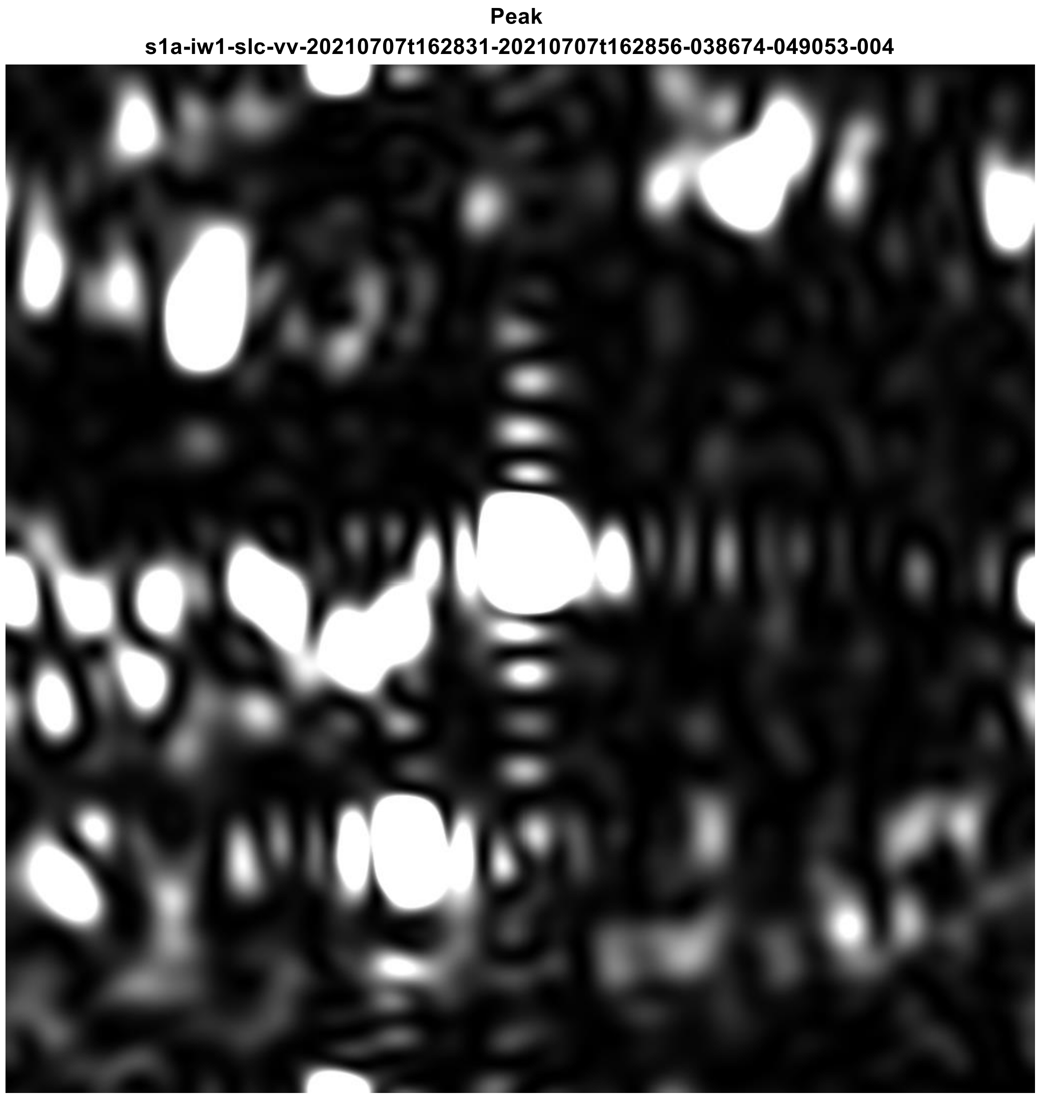
Sentinel-1 data availability for WLAD

Total	124
S1A	76
S1B	48
Ascending pass	63
Descending pass	61

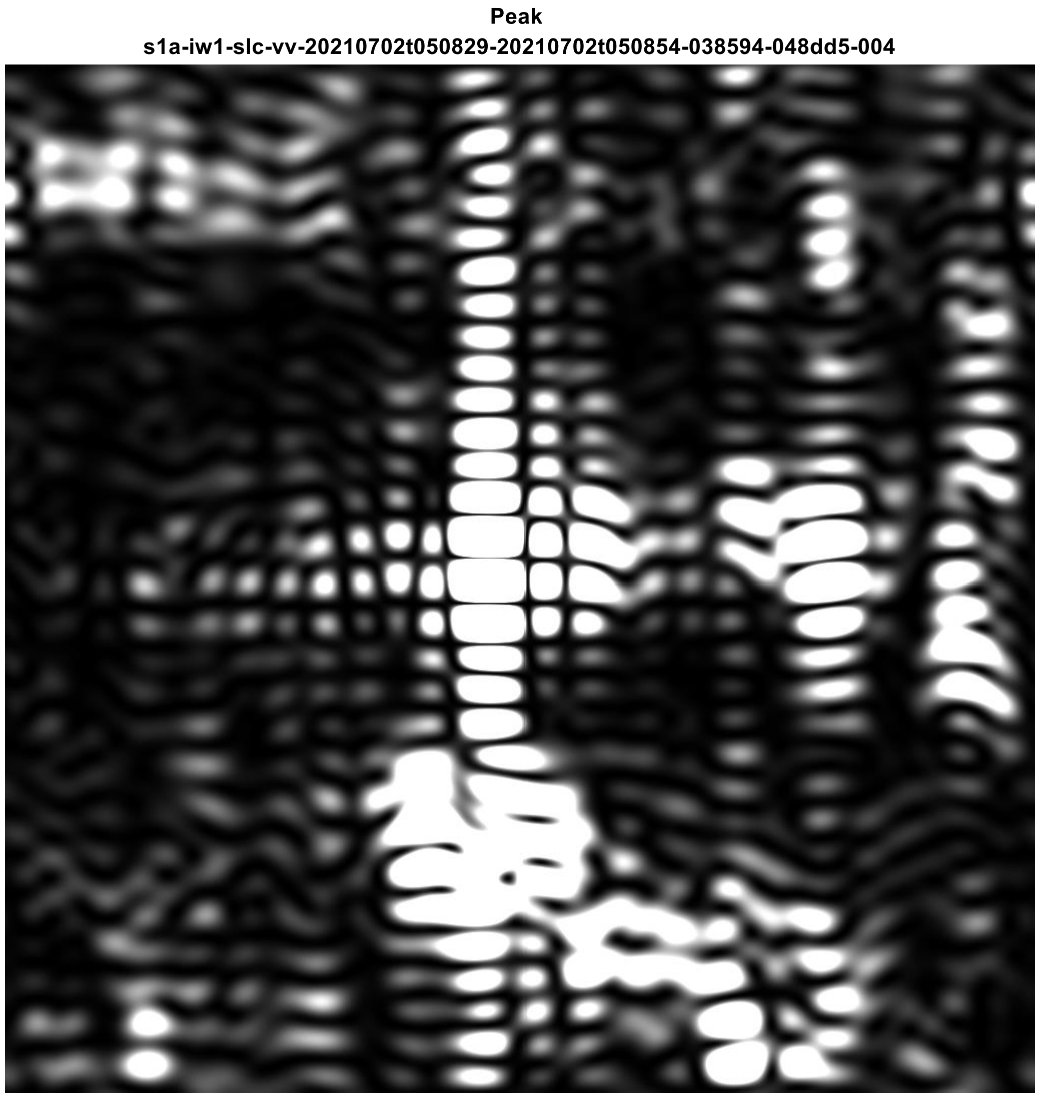


23.12.2021 – Sentinel-1B malfunction

Signals of ECR – WLAD site

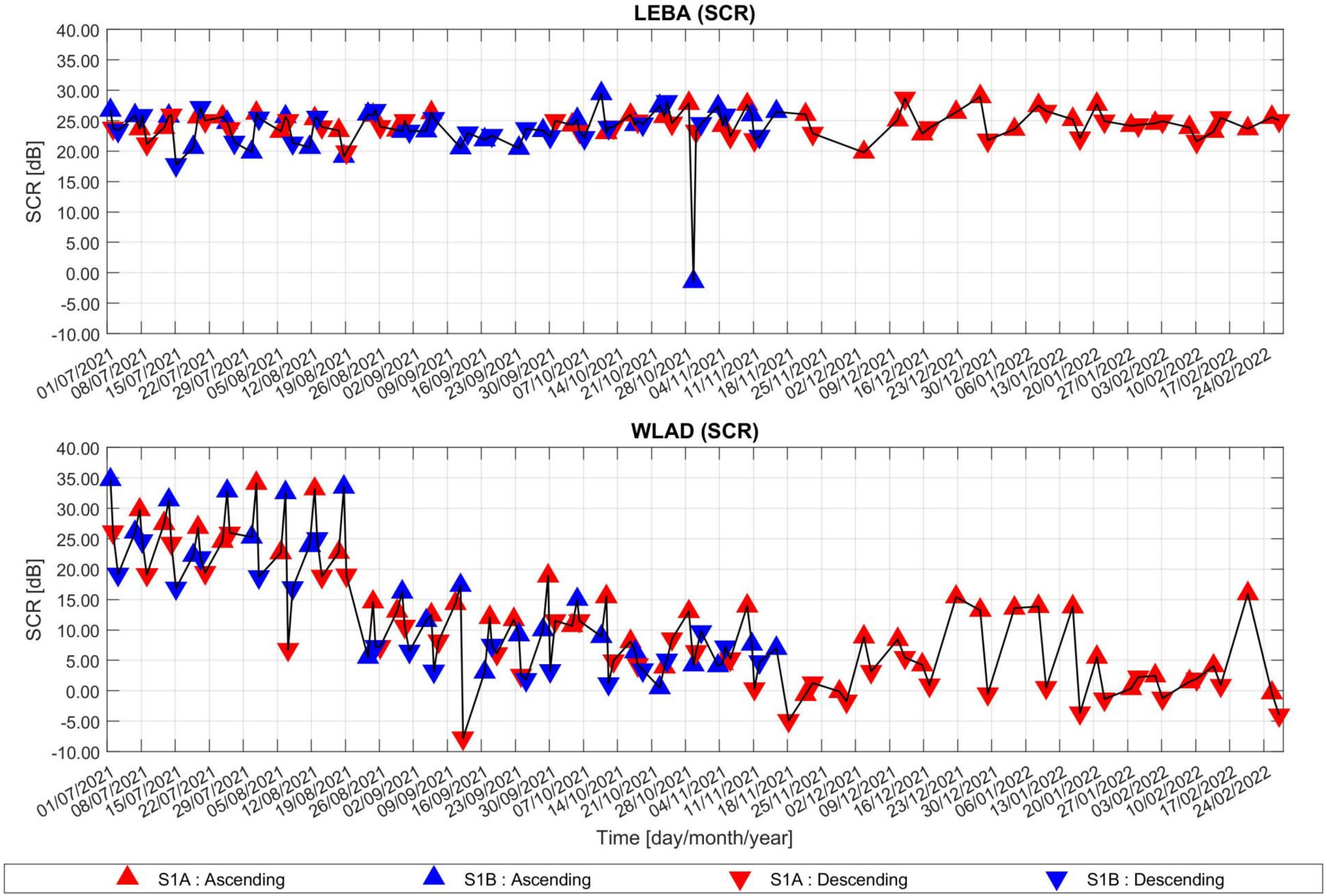


07.07.2021 – Sentinel-1A – Descending orbit



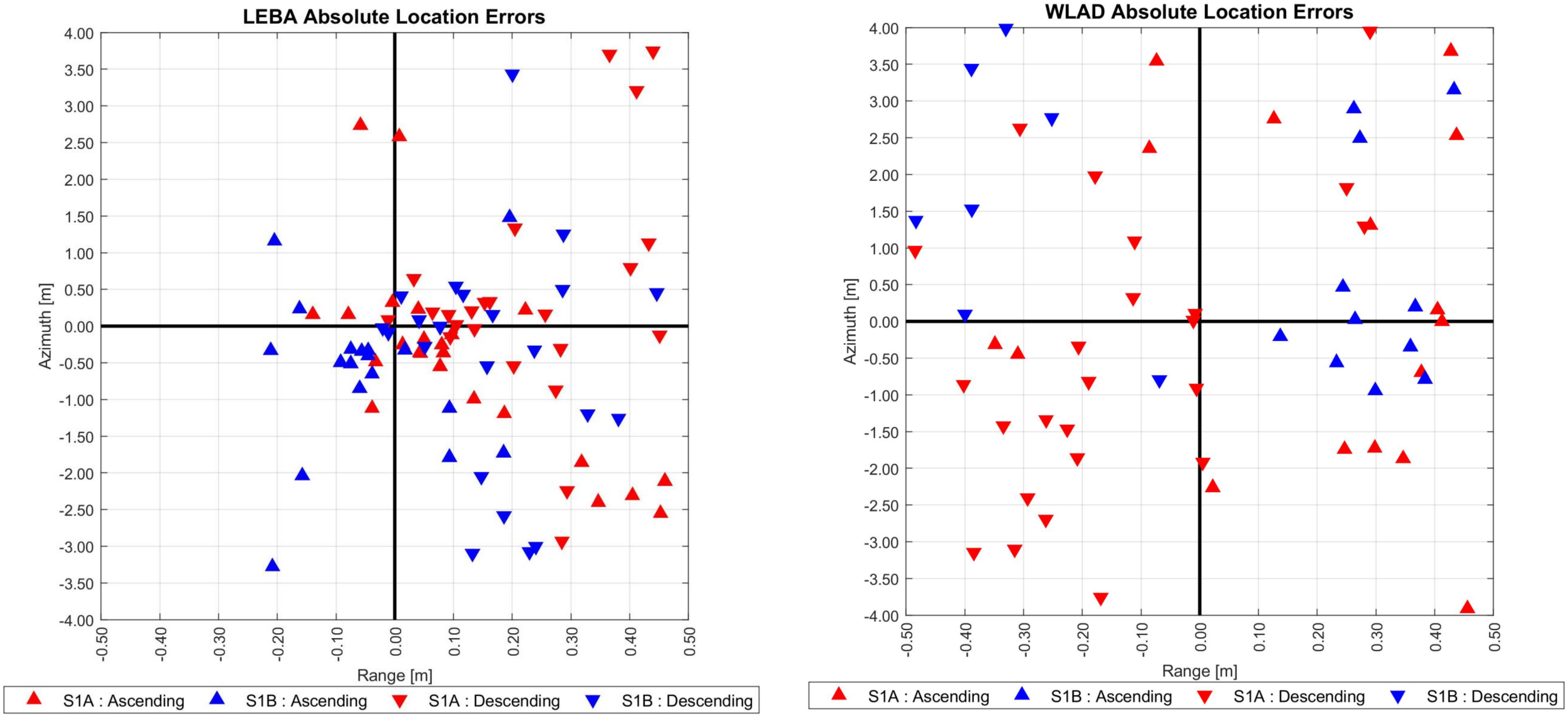
02.07.2021 – Sentinel-1A – Ascending orbit

Signal-to-clutter ratio (SCR)



Absolute Location Error

Difference in quality of the radar coordinates – please note the scales of range and azimuth axes!



Summary and conclusions

- Geodetic SAR potentially might be a great support and add value for geodesy in terms of collocation with GNSS stations and tide gauge stations.
- Active radar transponders most likely suffer from variable systematic electronic instrument delays. Each instrument needs to be calibrated before mounting on site. We will continue further evaluation of their activity parallel to software development and tuning.
- Since the Sentinel-1B malfunction, the number of free-of-charge images has been significantly reduced. Using data from constellations like Radarsat-2 and Radarsat Constellation might be very beneficial for this technique.

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Thank you for your attention

Additional material is in backup slides

Backup slides

Potential applications

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

Geodetic SAR measurement principle

(1) Precisely determined orbit

(2) SAR satellite

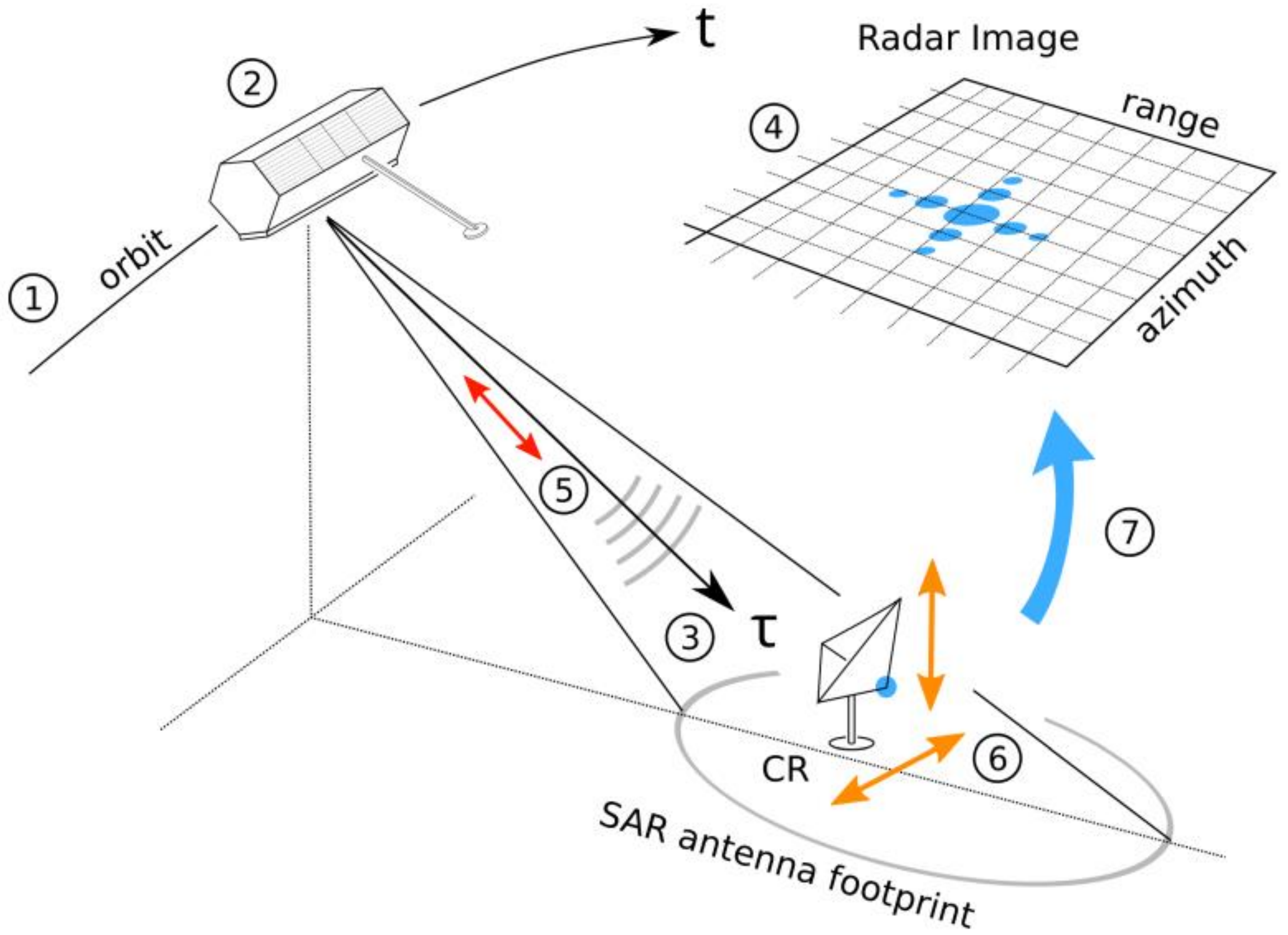
(3) Image acquisition

(4) Image generation

(5) Atmospheric signal delays

(6) Geodynamic effects

(7) Transponder position



Source: Gisinger, Christoph (2020) SAR Imaging Geodesy - Towards Absolute Coordinates with Centimeter Accuracy. Dissertation, Technische Universität München.

Electronic Corner Reflector vs Corner Reflector

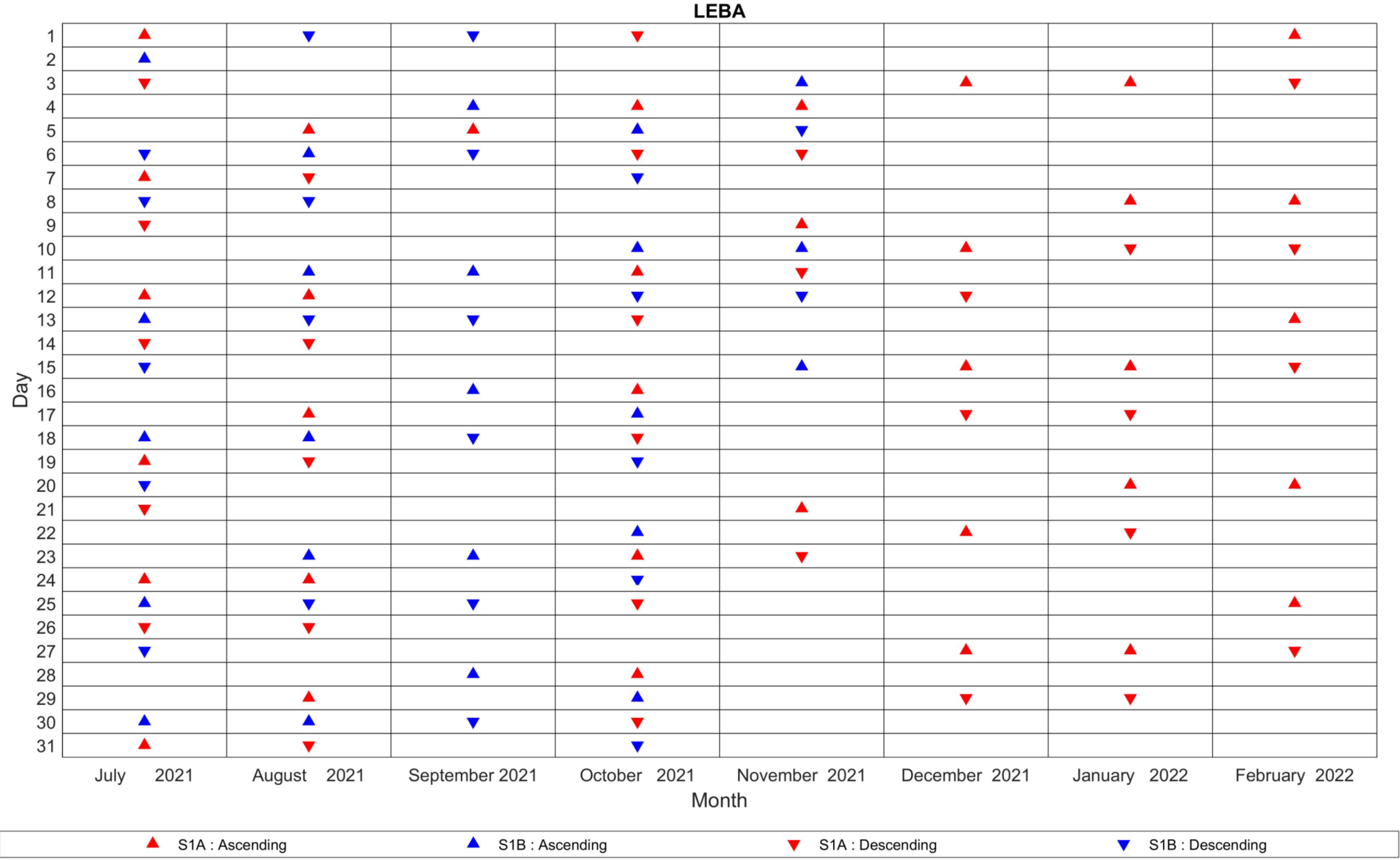
	ECR	CR
Ascending and descending orbits	✓	✗
Portability	✓	✗
Independence from power supply	✗	✓

1.5 m corner reflector of Metsähovi station (Finland) (picture from Survey Protocol for Geometric SAR Sensor Analysis, 2018
Authors: Ulrich Balss[1], Christoph Gisinger[2], Michael Eineder[1], Helko Breit[1], Adrian Schubert[3], David Small[3]

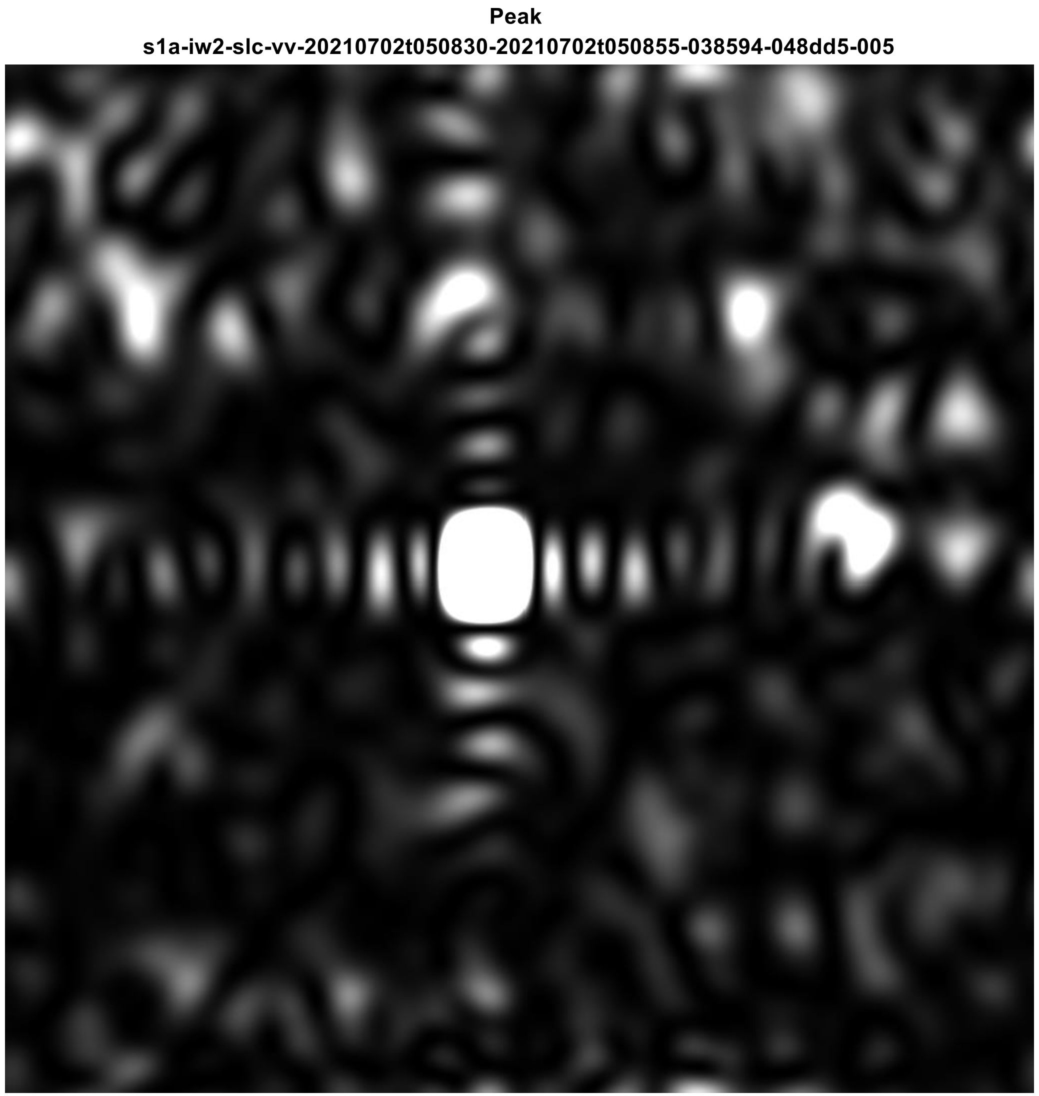
[1] German Aerospace Center, Germany
[2] Technical University of Munich, Germany
[3] Remote Sensing Laboratories – University of Zurich, Switzerland)

Sentinel-1 data availability for LEBA

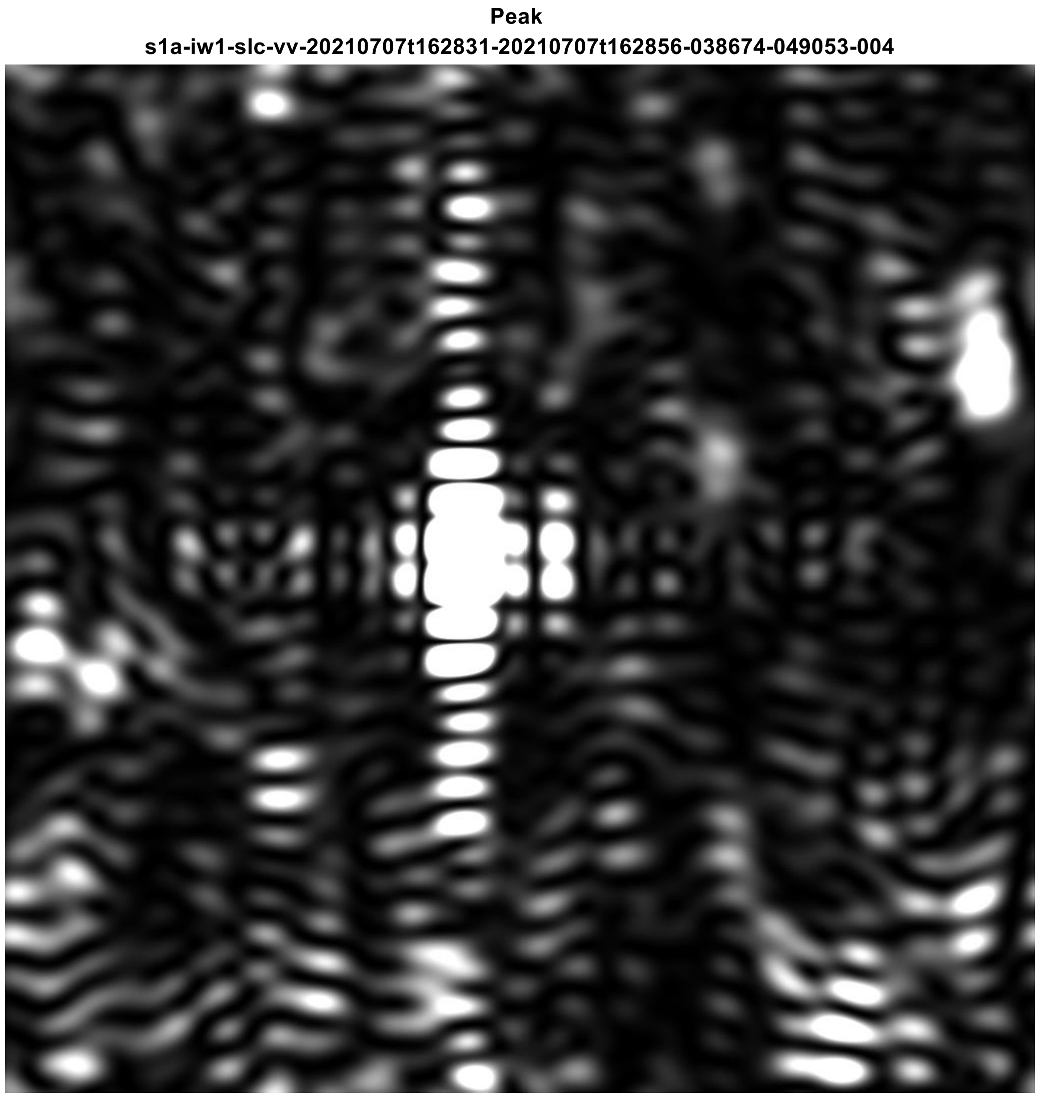
Total	110
S1A	64
S1B	46
Ascending pass	58
Descending pass	52



Signals of ECR – LEBA site

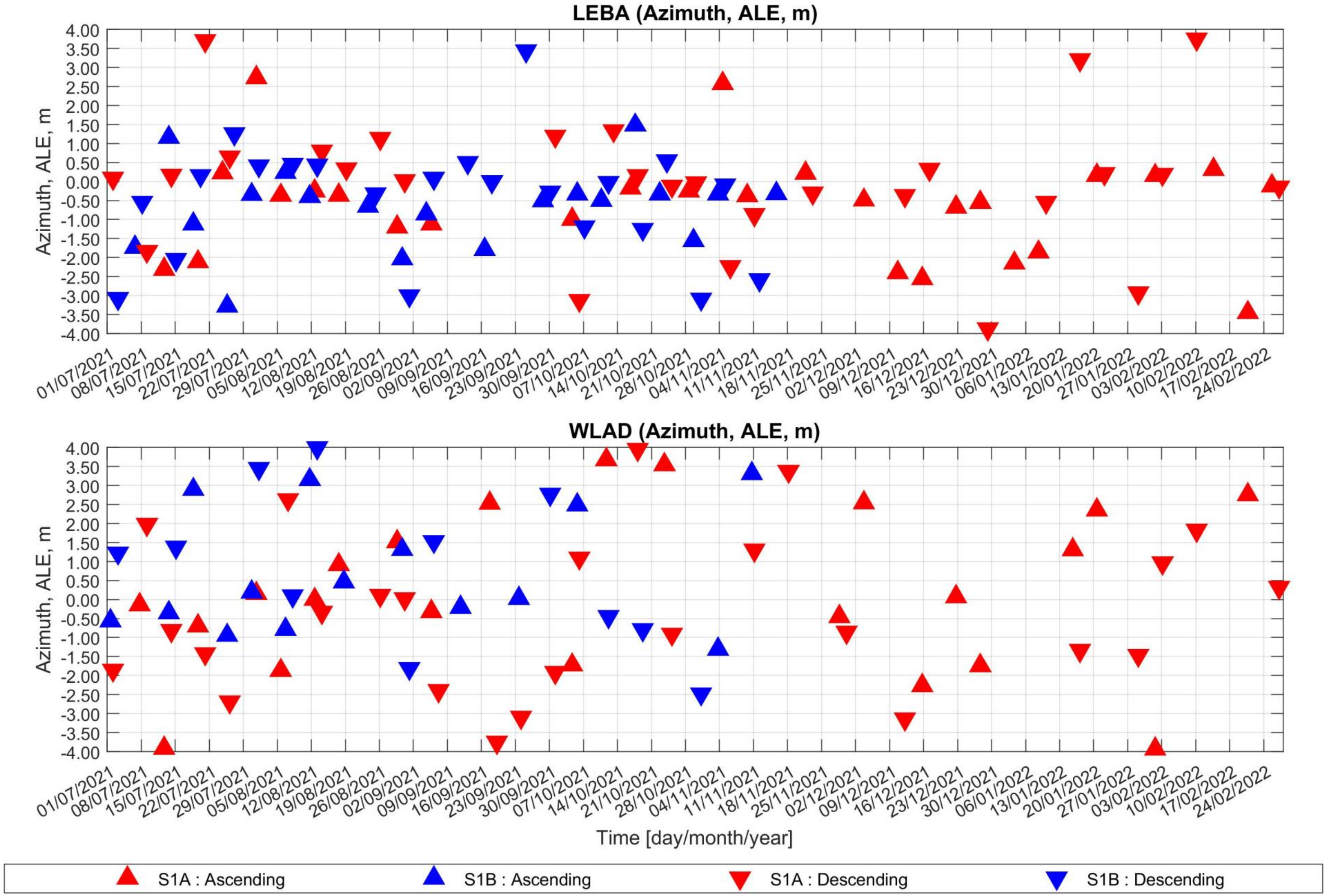


02.07.2021 – Sentinel-1A – Descending orbit



07.07.2020 – Sentinel-1A – Ascending orbit

Absolute Location Error in Azimuth



Absolute Location Error in Range