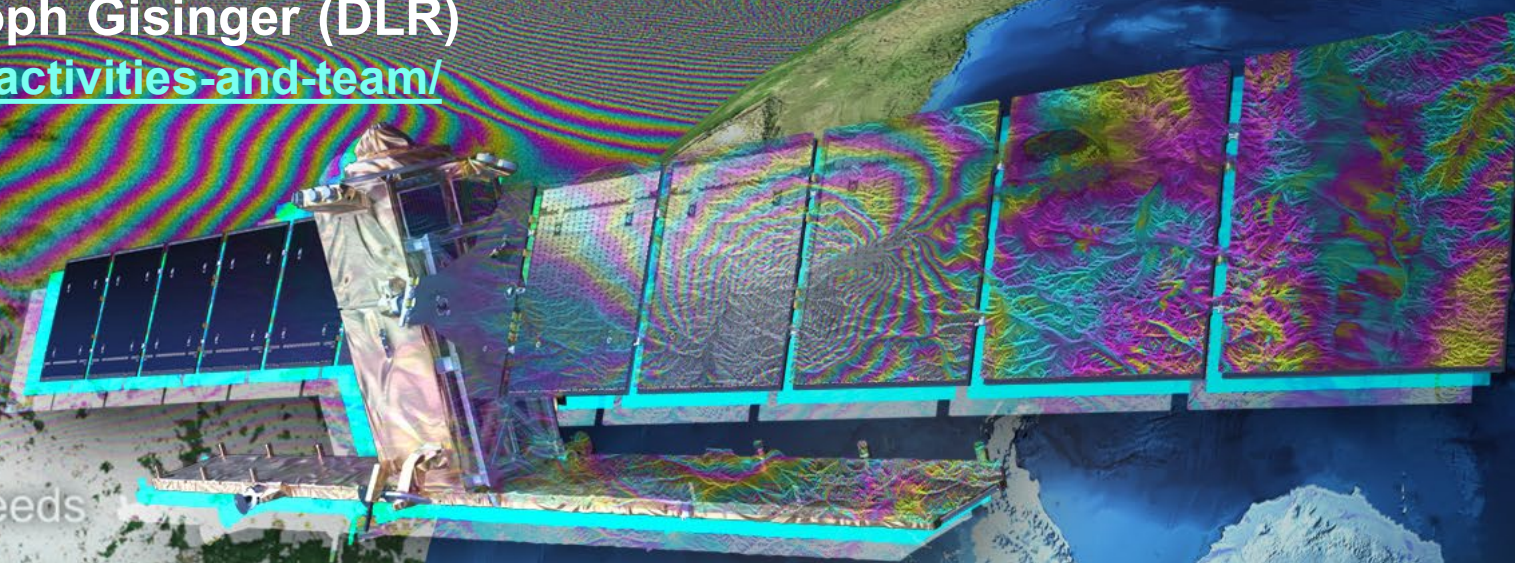# Sentinel-1 Product Performance

Muriel Pinheiro (ESA), Antonio Valentino (RHEA), Clément Albinet (ESA), Guillaume Hajduch (CLS), Pauline Vincent (CLS), Andrea Recchia (Aresys), Alessandro Cotrufo (Aresys), Kersten Schmidt (DLR), Christoph Gisinger (DLR)

https://sar-mpc.eu/about/activities-and-team/

FRINGE 2023

University of Leeds, UK | 11 - 15 September 2023.

SAR-MPC

→ THE EUROPEAN SPACE AGENCY

Outline

❑ Sentinel-1 SAR Mission Performance Cluster

❑ Highlights on instrument and data performance

❑ Highlights on products and evolutions

❑ Highlights on on-going activities

Outline

- Sentinel-1 SAR Mission Performance Cluster

- Highlights on instrument and data performance
  - ❖ R-6
- Highlights on products and evolutions
  - ❖ R-5, R-7, R-8
- Highlights on on-going activities
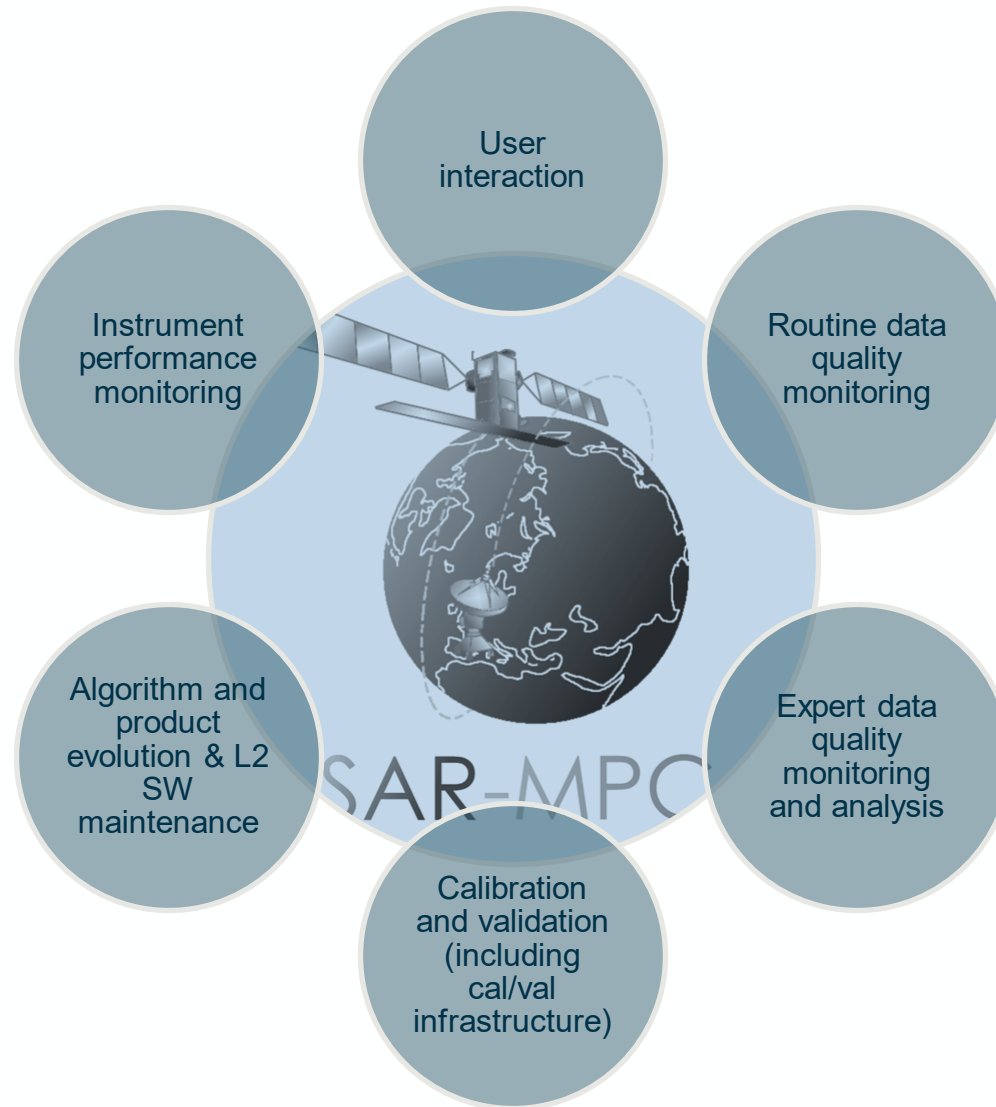 - ❖ R-1, R-26, R-46

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Outline
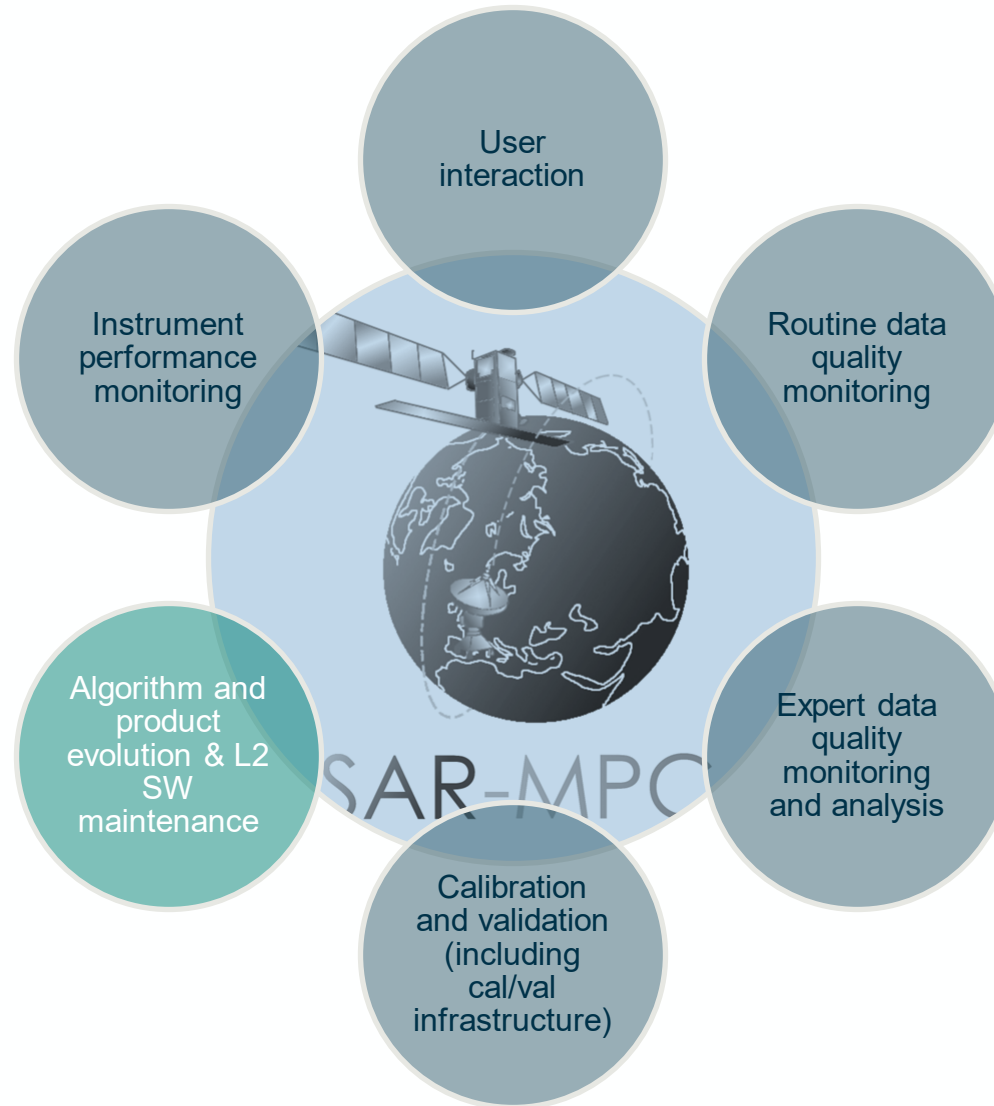
- **Sentinel-1 SAR Mission Performance Cluster**

- Highlights on instrument and data performance

- Highlights on products and evolutions

- Highlights on on-going activities

→ THE EUROPEAN SPACE AGENCY

Sentinel-1 SAR Mission Performance Cluster

Sentinel-1 SAR Mission Performance Cluster

IPF Versions

Documentation

- User interaction
- Routine data quality monitoring
- Expert data quality monitoring and analysis
- Calibration and validation (including cal/val infrastructure)
- Algorithm and product evolution & L2 SW maintenance
- Instrument performance monitoring

SAR-MPC

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Sentinel-1 SAR Mission Performance Cluster

User interaction

Routine data quality monitoring

Instrument performance monitoring

Algorithm and product evolution & L2 SW maintenance

Expert data quality monitoring and analysis

Calibration and validation (including cal/val infrastructure)

SAR-MPC

Annual Performance Report 2022

Quality Disclaimers

→ THE EUROPEAN SPACE AGENCY

Sentinel-1 SAR Mission Performance Cluster

- User interaction
- Routine data quality monitoring
- Expert data quality monitoring and analysis
- Calibration and validation (including cal/val infrastructure)
- Algorithm and product evolution & L2 SW maintenance
- Instrument performance monitoring
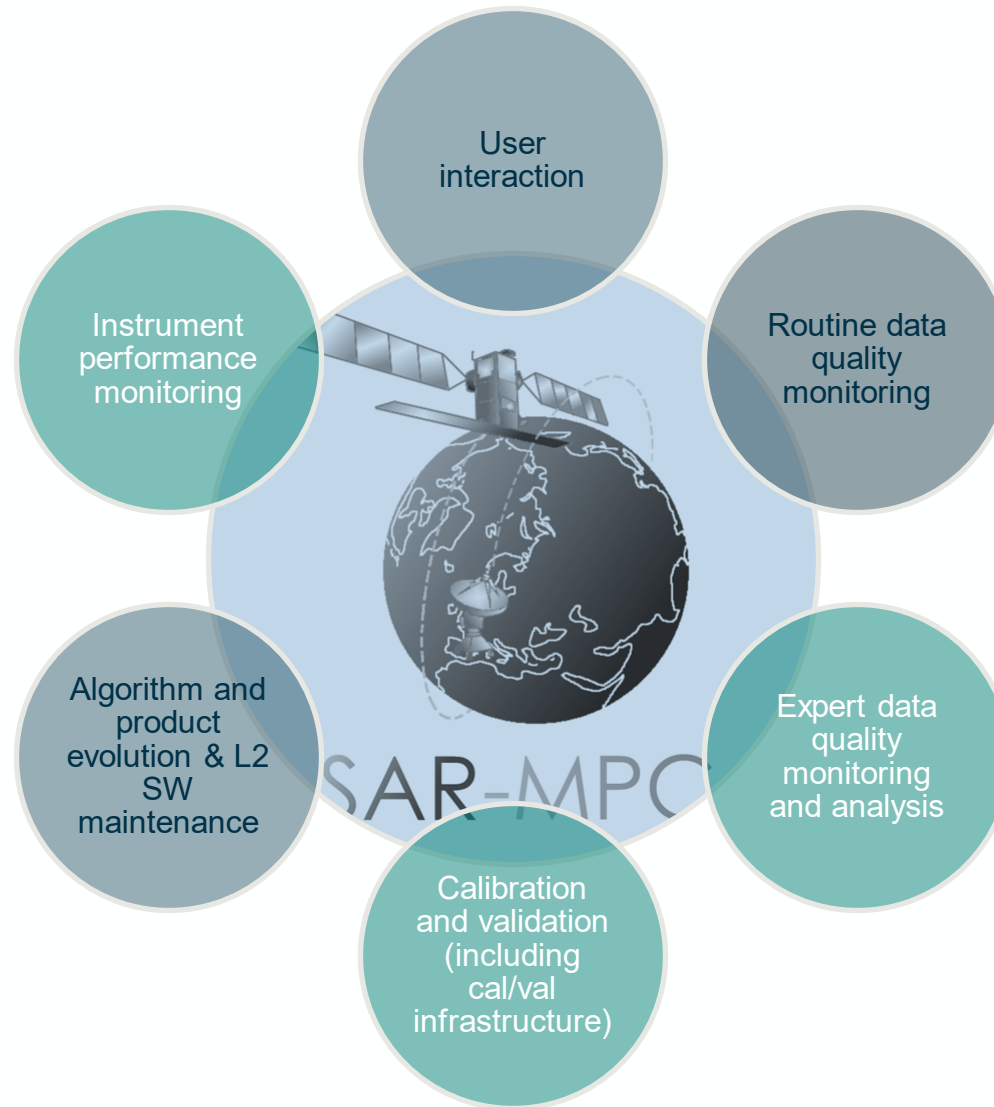
Quality Disclaimers

- Single events, e.g., for data processed without POD orbits (see here)
- Monthly for known recurring anomalies, e.g., RFI residual, Burst ID, POD-related (see here, here and here)

Time: 12/Sept/2023: 4:30pm-7:00pm
Copernicus Sentinel-1 Satellites - Nine Years of Operational Orbit Determination at the Copernicus POD Service
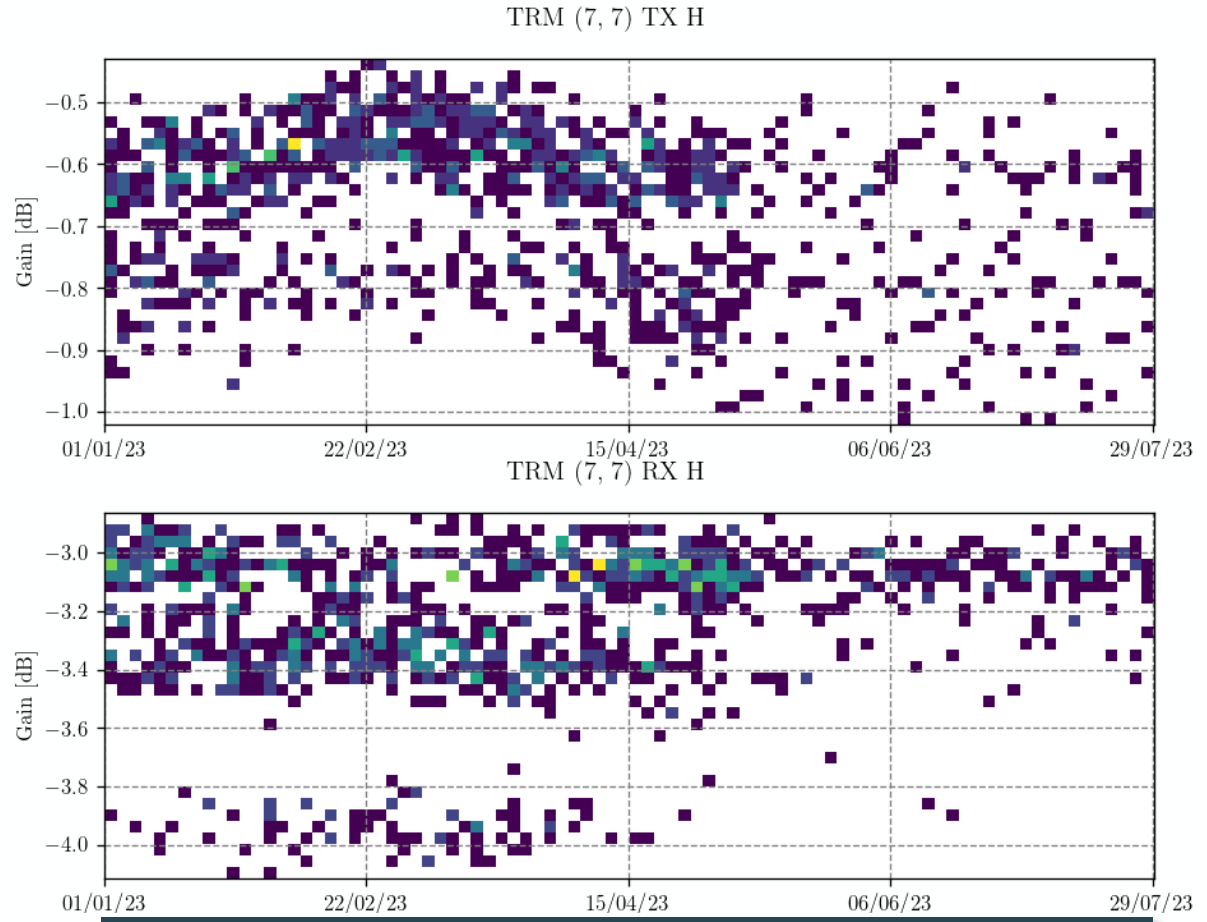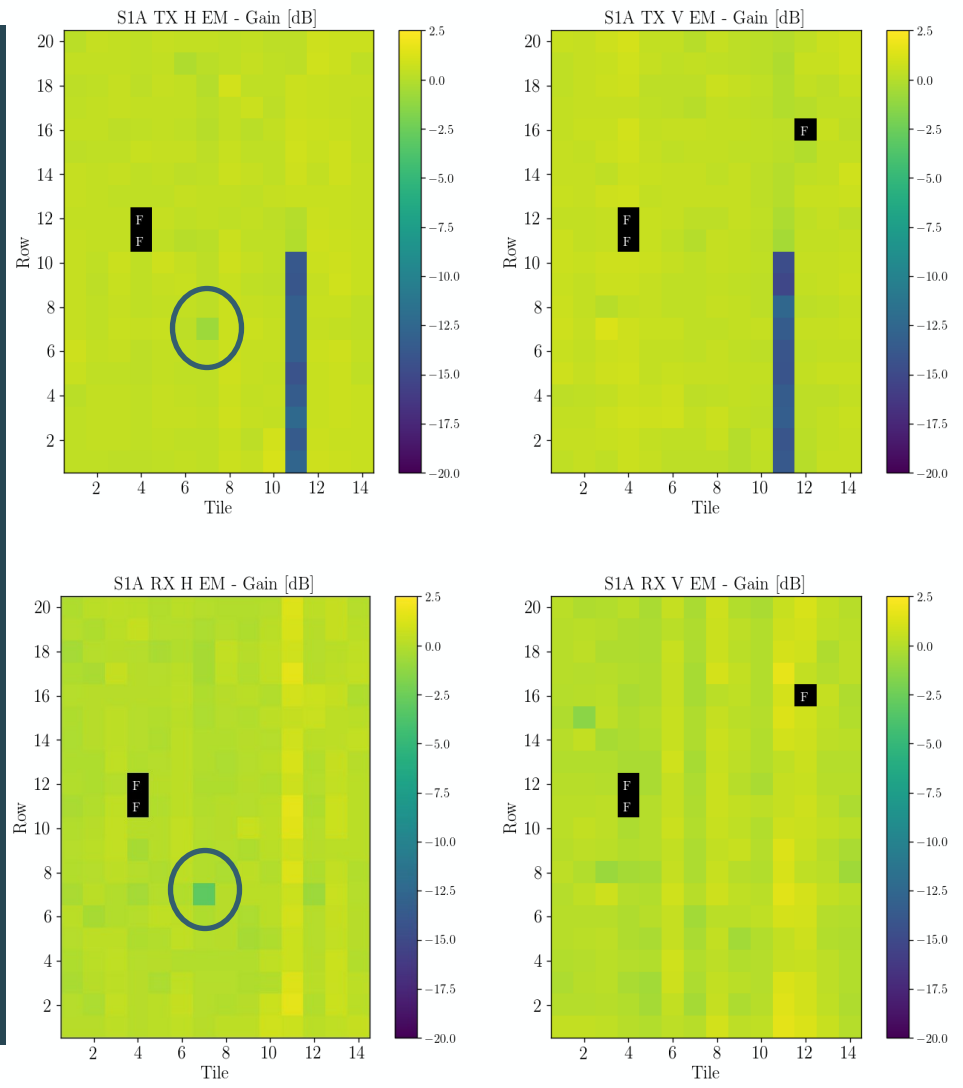
Sentinel-1 SAR Mission Performance Cluster
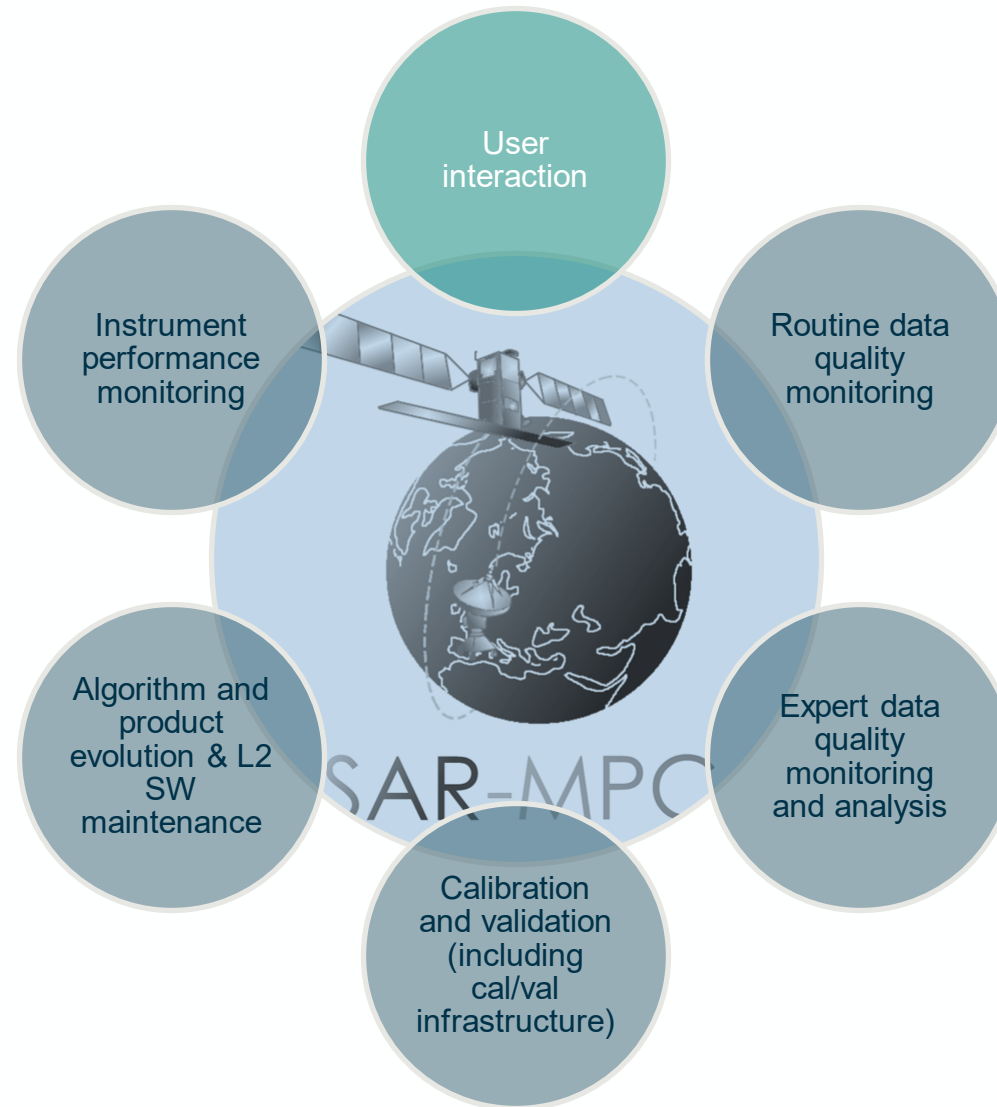
Contact us!

muriel.pinheiro@esa.int
eosupport@copernicus.esa.int

Outline

❑ Sentinel-1 SAR Mission Performance Cluster

❑ **Highlights on instrument and data performance**

❑ Highlights on products and evolutions

❑ Highlights on on-going activities

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Antenna Error Matrix - July 2023

S1A TX H EM - Gain [dB]

S1A TX V EM - Gain [dB]

S1A RX H EM - Gain [dB]

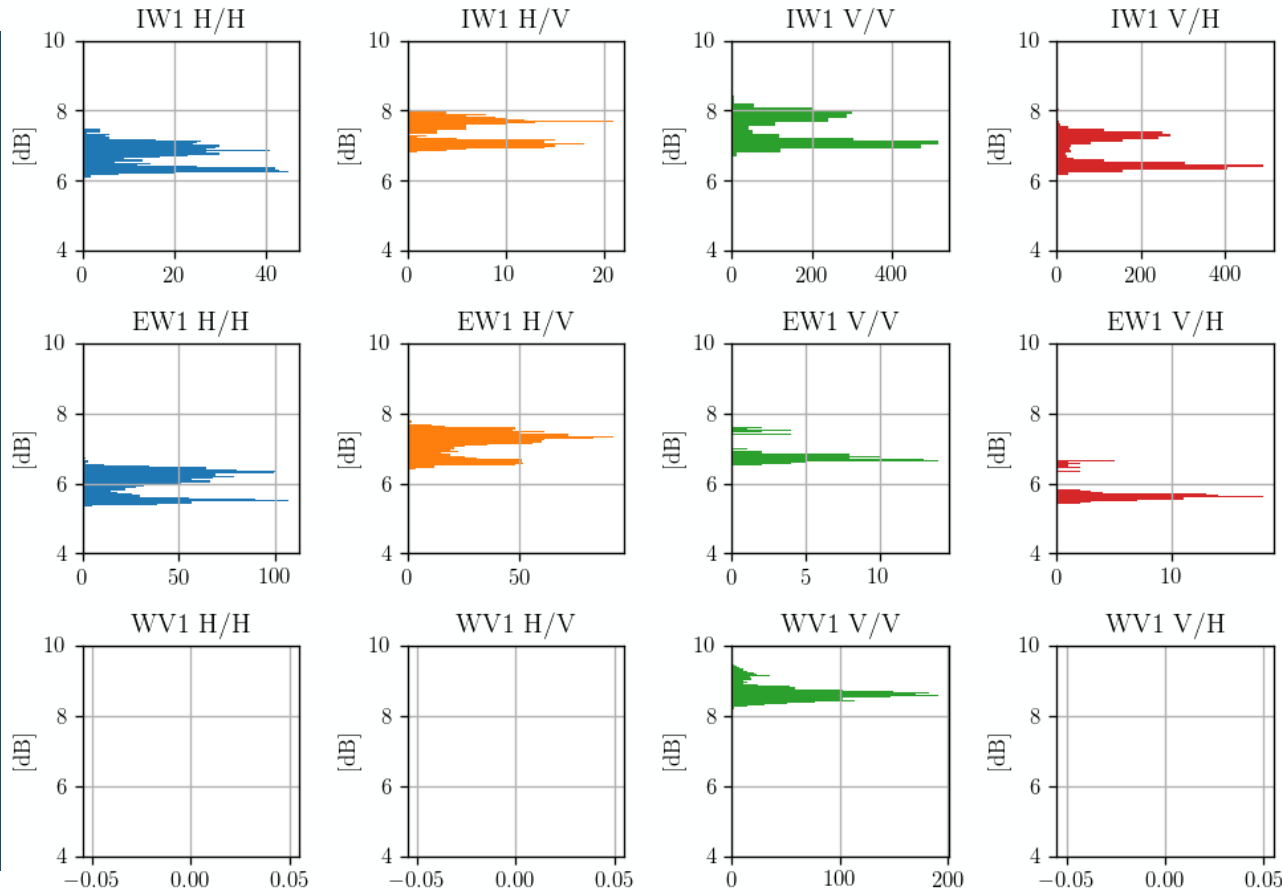S1A RX V EM - Gain [dB]

TRM (7, 7) TX H

TRM (7, 7) RX H

Antenna status is stable. Small jump in 2021 closely monitored and currently doesn't impact image quality

Instrument Performance: noise

Noise level distribution - April 2023

SSW	Pol	Noise level at sea [dB] (average over month)	Difference w.r.t. previous year [dB]	Noise level at land [dB] (average over last month)	Difference w.r.t. previous year [dB]
IW 1	H/H	6.32	0.02	6.91	-0.02
	H/V	7.05	0	7.68	-0.01
	V/V	7.07	0	7.85	-0.01
	V/H	6.41	0.02	7.24	0.02
IW 2	H/H	5.97	0.03	6.6	-0.01
	H/V	6.82	0	7.43	-0.02
	V/V	6.79	-0.02	7.56	-0.07
	V/H	6.04	0.01	6.95	0.02
IW 3	H/H	6.28	0.02	6.97	0
	H/V	7.26	0.01	7.88	-0.01
	V/V	7.27	-0.01	7.99	-0.04
	V/H	6.37	0.02	7.33	0.03

S1A baselines w.r.t. reference cycle
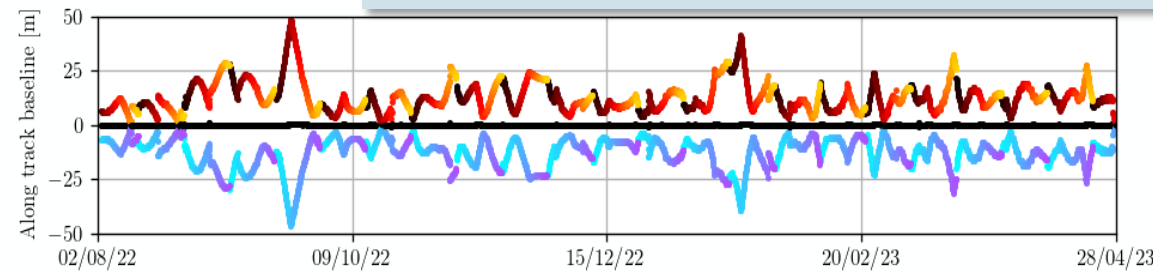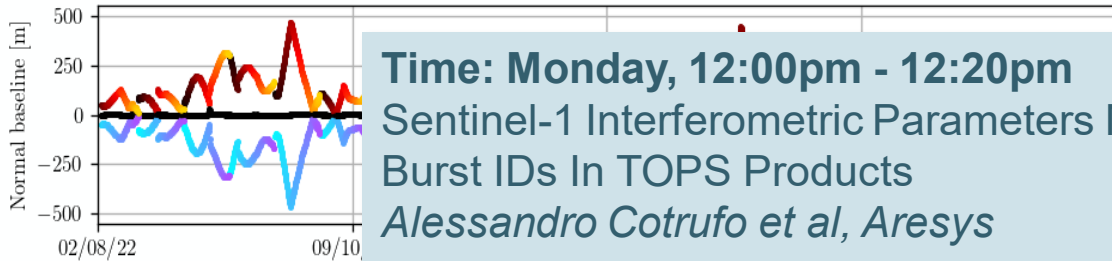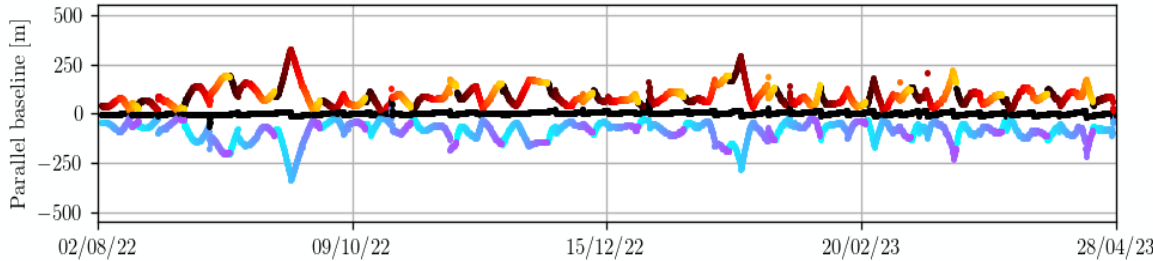
Time: Monday, 12:00pm - 12:20pm
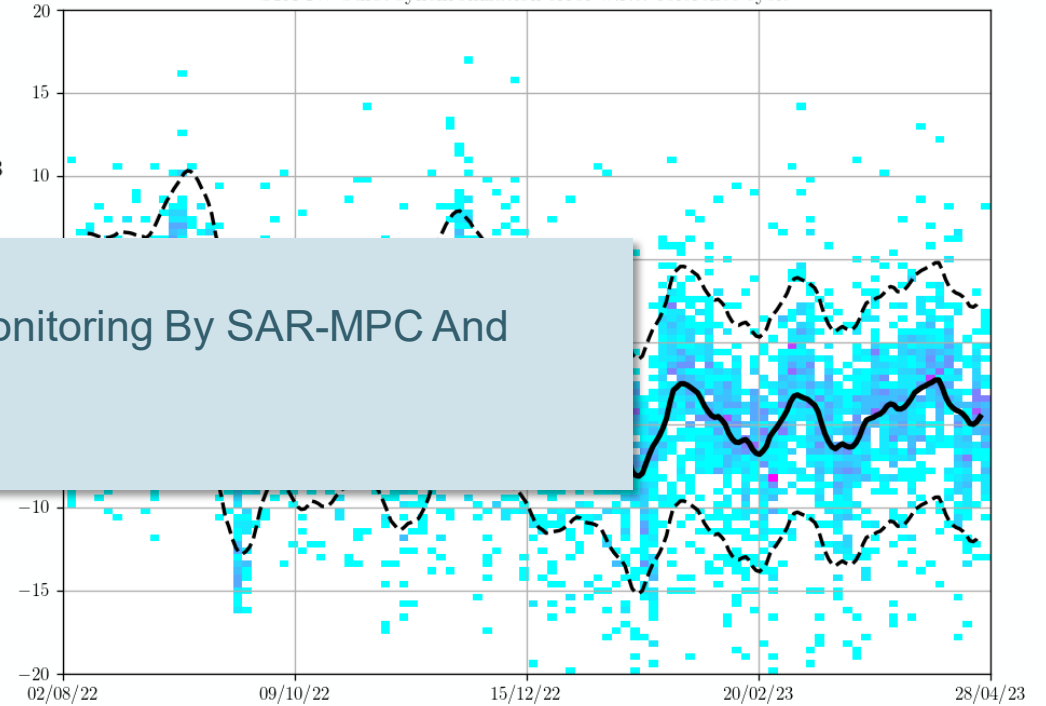Sentinel-1 Interferometric Parameters Monitoring By SAR-MPC And Burst IDs In TOPS Products
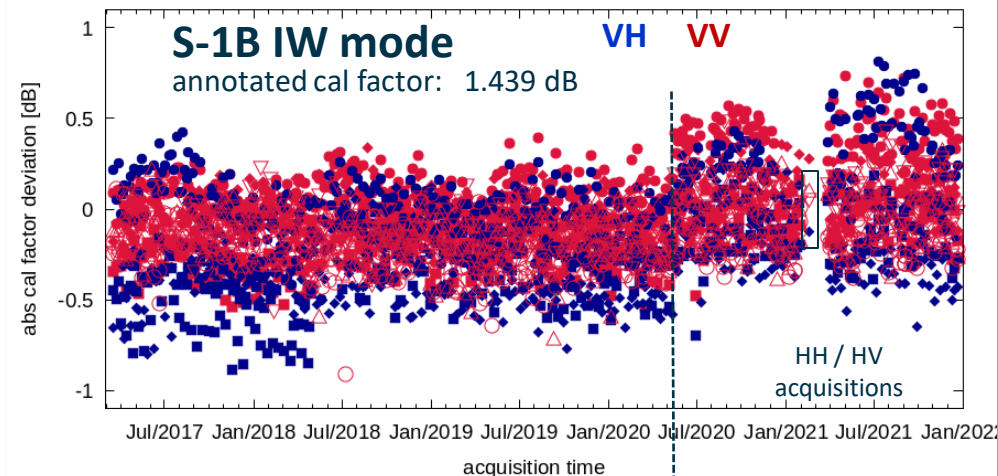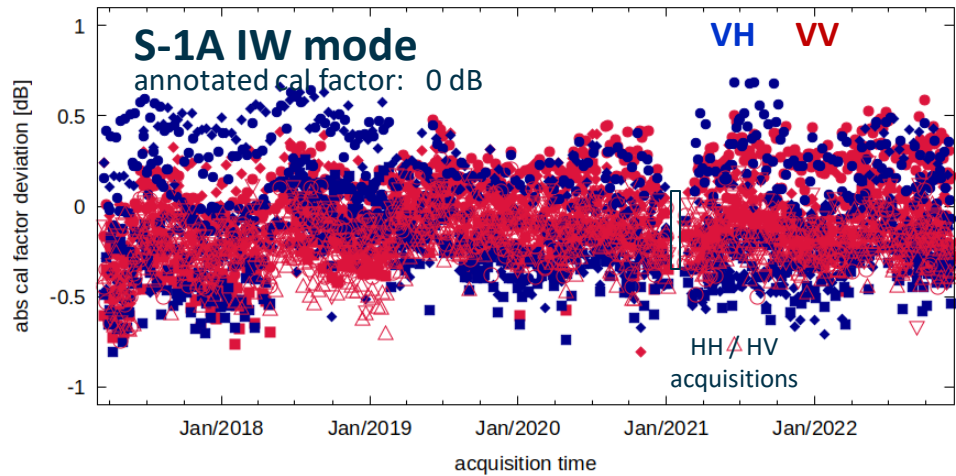*Alessandro Cotrufo et al, Aresys*

S1A IW burst synchronization error w.r.t. reference cycle

Well controlled baseline

Small synchronization error

L1: radiometric calibration and performance

S-1A IW mode — annotated cal factor: 0 dB
S-1B IW mode — annotated cal factor: 1.439 dB

EAP change

	S-1A		S-1B	
	μ [dB]	σ [dB]	μ [dB]	σ [dB]
IW1 VV	-0.13	0.23	-0.02	0.22
IW1 VH	-0.20	0.24	-0.20	0.29
IW1 VV&VH	**-0.16**	**0.24**	**-0.09**	**0.26**
IW2 VV	-0.11	0.17	-0.12	0.17
IW2 VH	-0.00	0.30	-0.25	0.25
IW2 VV&VH	**-0.08**	**0.21**	**-0.15**	**0.20**
IW3 VV	-0.05	0.23	-0.02	0.20
IW3 VH	0.08	0.30	-0.04	0.26
IW3 VV&VH	**0.00**	**0.27**	**-0.03**	**0.23**
IW 1-3 VV	-0.10	0.21	-0.06	0.21
IW 1-3 VH	-0.09	0.30	-0.17	0.28
IW 1-3 VV&VH	**-0.104**	**0.242**	**-0.096**	**0.240**

Derived radiometric accuracy

	S-1A	S-1B
absolute radiometric accuracy (1σ)*	0.325 dB	0.323 dB

* including
Long term stability of the instrument 0.05 dB (1σ)
Dynamic range error 0.067 dB (1σ)
Reference target accuracy 0.20 dB (1σ)

Radiometric accuracy continues to be within mission requirements and stable over time

L1: radiometric calibration and performance

S-1A IW mode — annotated cal factor: 0 dB (VH, VV)

S-1B IW mode — annotated cal factor: 1.439 dB (VH, VV)

With EAP re-compensation

Derived radiometric accuracy

	S-1A	S-1B
absolute radiometric accuracy (1σ)*	0.298 dB	0.302 dB

* including

Long term stability of the instrument	0.05 dB (1σ)
Dynamic range error	0.067 dB (1σ)
Reference target accuracy	0.20 dB (1σ)

More info: Radiometric Re-Compensation of Sentinel-1 SAR Data Products for Artificial Biases due to Antenna Pattern Changes

	S-1A		S-1B	
	μ [dB]	σ [dB]	μ [dB]	σ [dB]
IW1 VV	-0.07	0.19	0.16	0.16
IW1 VH	-0.24	0.18	0.00	0.18
IW1 VV&VH	**-0.14**	**0.20**	**0.10**	**0.19**
IW2 VV	-0.07	0.16	0.00	0.20
IW2 VH	-0.08	0.26	-0.11	0.26
IW2 VV&VH	**-0.07**	**0.18**	**-0.02**	**0.22**
IW3 VV	-0.04	0.21	0.00	0.20
IW3 VH	0.00	0.23	-0.05	0.19
IW3 VV&VH	**-0.02**	**0.22**	**-0.02**	**0.20**
IW 1-3 VV	-0.07	0.18	0.07	0.20
IW 1-3 VH	-0.15	0.23	-0.04	0.21
IW 1-3 VV&VH	**-0.09**	**0.204**	**0.04**	**0.210**

- (Up to 2021): Unexplained biases between S1A and S1B in HH, but not in VV,
    - hinting at problems with HH calibration
    - behaviour not consistent for IW and EW
- Changes in acquisition scenario to support radiometric calibration:
    - Alternating HH/VV over CSA transponders, **in cooperation with CSA for transponder activation**
    - Alternating HH/VV over Surat
    - Change in acquisition pattern over rain forest: alternating HH/VV and EW/IW and including overlap between modes with similar geometries
- Plan started to be implemented November 2022 and results are currently being evaluated

Surat Basin
S1A Azimuth vs Range ALE [m]

	Range ALE [m]	Azimuth ALE [m]
Sentinel-1A	**-3,496 +/- 0,374**	**2,131 +/- 0,842**
IW-1	-3,347 +/- 0,294	2,816 +/- 0,393
IW-2	-3,484 +/- 0,348	2,090 +/- 0,358
IW-3	-3,784 +/- 0,371	0,923 +/- 0,419

Swath
- IW1
- IW2
- IW3

Orbit direction + Polarization
- ASCENDING H/H
- ASCENDING V/V
- DESCENDING H/H
- DESCENDING V/V

April 2022 – May 2023

Out-of-the-box (OOB) accuracy under 7m (3sigma)
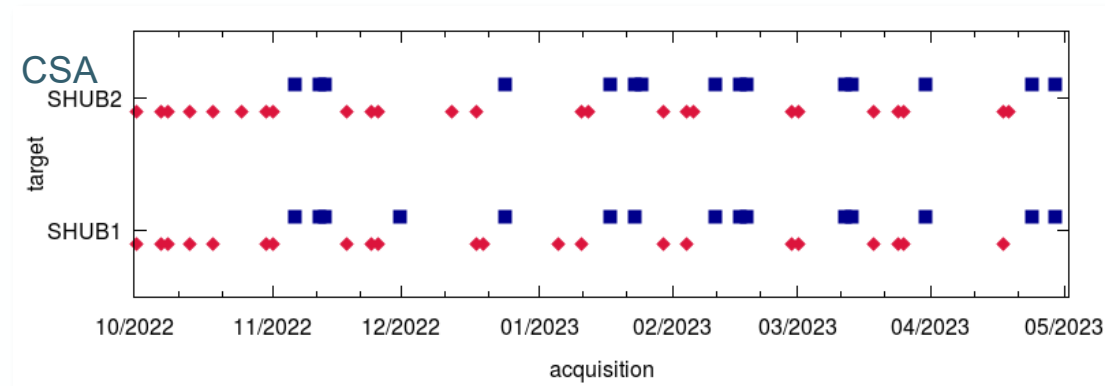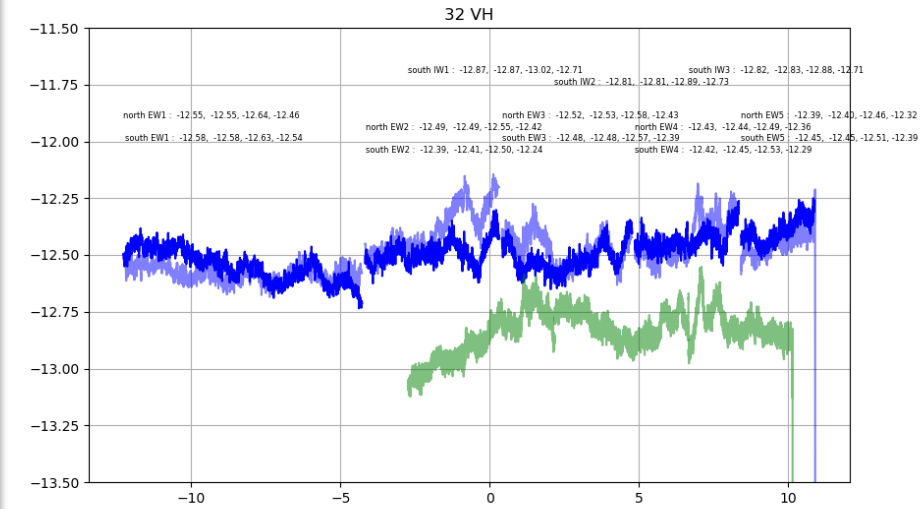
L1: Absolute Location Error (ALE)

Surat Basin
S1A Azimuth vs Range ALE [m]

	Range ALE [m]	Azimuth ALE [m]
Sentinel-1A	0,024 +/- 0,060	-0,146 +/- 331
IW-1	0,019 +/- 0,057	-0,301 +/- 0,305
IW-2	0,017 +/- 0,058	0,026 +/- 0,275
IW-3	0,042 +/- 0,063	-0,087 +/- 0,315

Swath
- IW1
- IW2
- IW3

Orbit direction + Polarization
ASCENDING H/H
ASCENDING V/V
DESCENDING H/H
DESCENDING V/V

April 2022 – May 2023
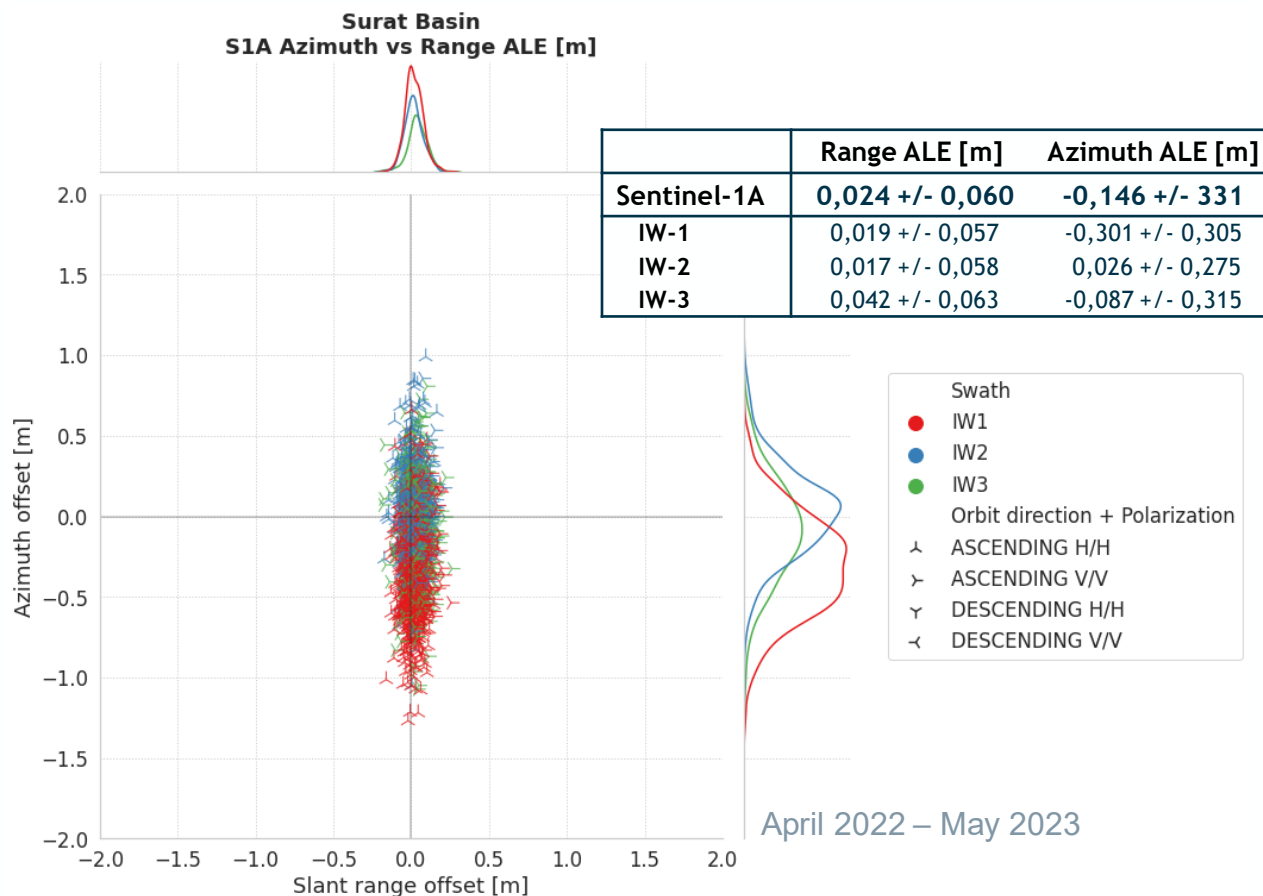
Decimetre accuracy after considering environment and system corrections (including antenna failure)

Metsähovi (Oct. 2013):
1 CR (1.5 m) – **D**
Local ties (< 5 mm)

DLR SCC (2014):
3 CR (2.8 m) – **A/D**
DGPS survey (TBC)

OCA GRAS (Jul. 2018):
1 CR (1.5 m) – **D**
Local ties (< 5 mm)

Rosamond (Nov. 2015):
13 CR (2.4 m) – **A, 10 CR** (2.4 m) – **D**
5 CR (4.8 m) – **D**

Wettzell (Jul. 2011, Oct. 2013):
1 CR (1.5 m) – **A, 1 CR** (1.5 m) – **D**
Local ties (< 5 mm)

R-6
Offset between S1A and S1B

In relation to ETAD:
- Time offsets have been recalibrated using different sites (AUX_ITC)
- Offsets should enable S1A and S1B ALE bias closer to 0m
- Inter-beam offset under analysis

Yarragadee (Aug. 2018):
1 CR (1.5 m) – **A, 1 CR** (1.5 m) – **D**
Local ties (< 15 mm)

Surat Basin (Nov. 2014):
40 CR (1.5 / 2.0 / 2.5 m) – **A**
DGPS survey (< 3 cm)

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Geodetic Observatories
S1A Azimuth vs Range ALE [m]

	Range ALE [m]	Azimuth ALE [m]
Sentinel-1A	**0.037 +/- 0.053**	**-0.055 +/- 0.377**
IW-1	0.025 +/- 0.050	-0.078 +/- 0.384
IW-2	0.032 +/- 0.052	-0.009 +/- 0.360
IW-3	0.066 +/- 0.051	-0.136 +/- 0.396

Swath
● IW1
● IW2
● IW3

Orbit direction + Polarization
⋏ ASCENDING H/H
⊁ ASCENDING V/V
Y DESCENDING H/H
⊰ DESCENDING V/V

April 2022 – May 2023
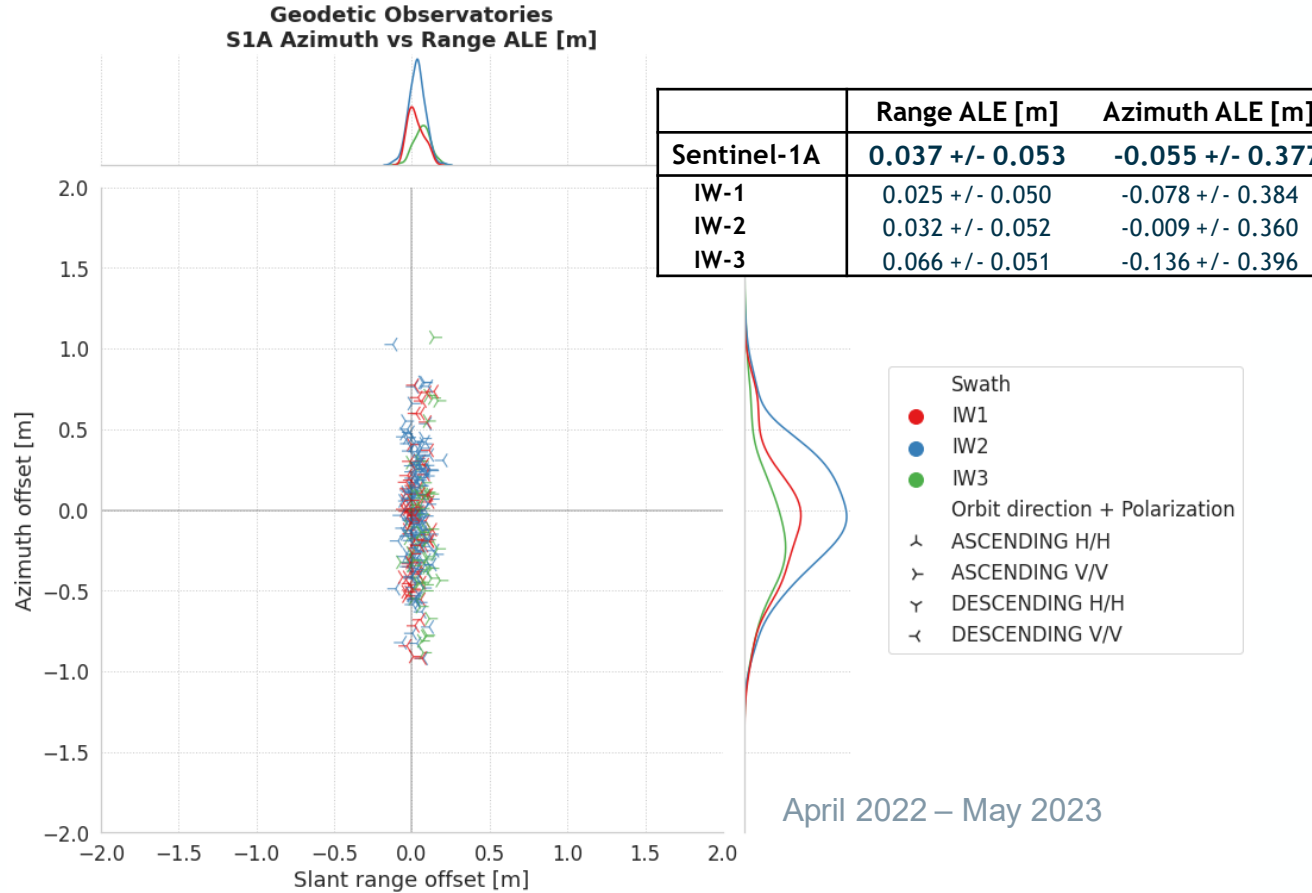
Joined Results WTZ, MET, OCA, YAR

TN coming soon!

AUX_ITC

21

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Outline

❏ Sentinel-1 SAR Mission Performance Cluster

❏ Highlights on instrument and data performance

❏ **Highlights on products and evolutions**

❏ Highlights on on-going activities

→ THE EUROPEAN SPACE AGENCY

L1: RFI mitigation and monitoring

- RFI **detection** and new RFI **annotations** available since **November 04, 2021.**

- **Test campaign in the ground segment for:**

  - Statistical analysis

  - Tunning of processing parameters

  - Assessment o

  - Assessment o including InSA

> **Time: Monday, 12:20pm - 12:40pm**
> Improvement Of Interferometric Coherence Through RFI Mitigation In Sentinel-1 Products
> *Andrea Recchia et al, Aresys*

- Operational **filtering** of RFI contamination in Sentinel-1 data was **activated on March 23, 2022,** after extensive validation and tunning.

No correction

IPF RFI correction
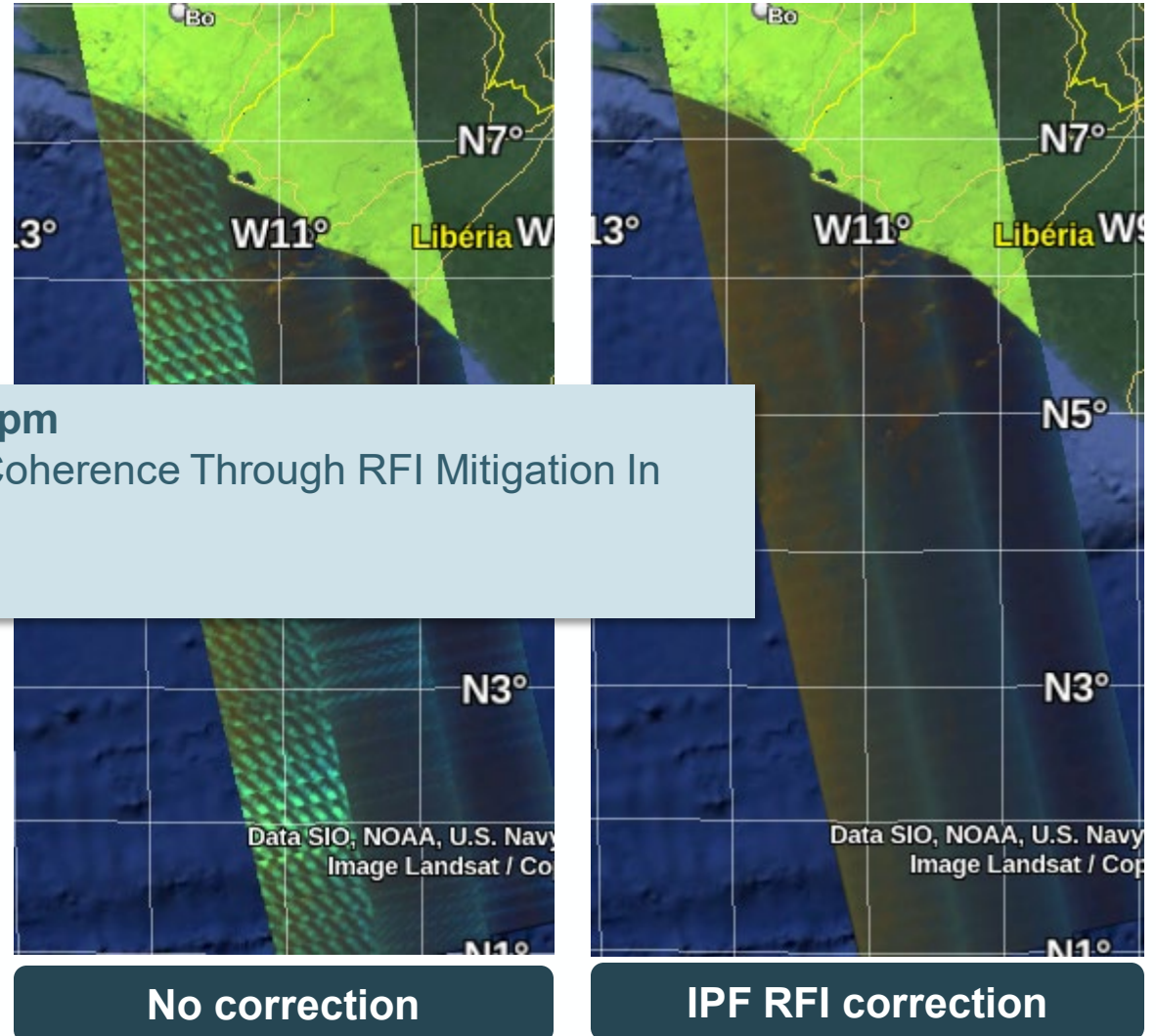
L1: RFI mitigation and monitoring

Residual RFI from RCM
48 occurrences from RCM constellation in 2022, limited to Indonesia

RFI residuals from quick-look inspection: estimated drop from 20% to about 1% of impacted slices

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Extend Time Annotation Product (ETAD)

- Geometry accuracy shown previously is accessible by putting in place several corrections.

- These corrections are easily obtained and applied using the new **S1 ETAD product.**

- Since April 2023, processor has been deployed and it is running in the ground segment.

- Cal/Val approach currently being consolidated, and the product quality is being monitored.

- Dissemination should start at the end of the year.

R-5, R-7, R-8
ETAD, provision of data for co-registration support, e.g., geodetic layers

Sentinel-1A data-take over Alaska, USA 2020-01-28 16:26:52 UTC

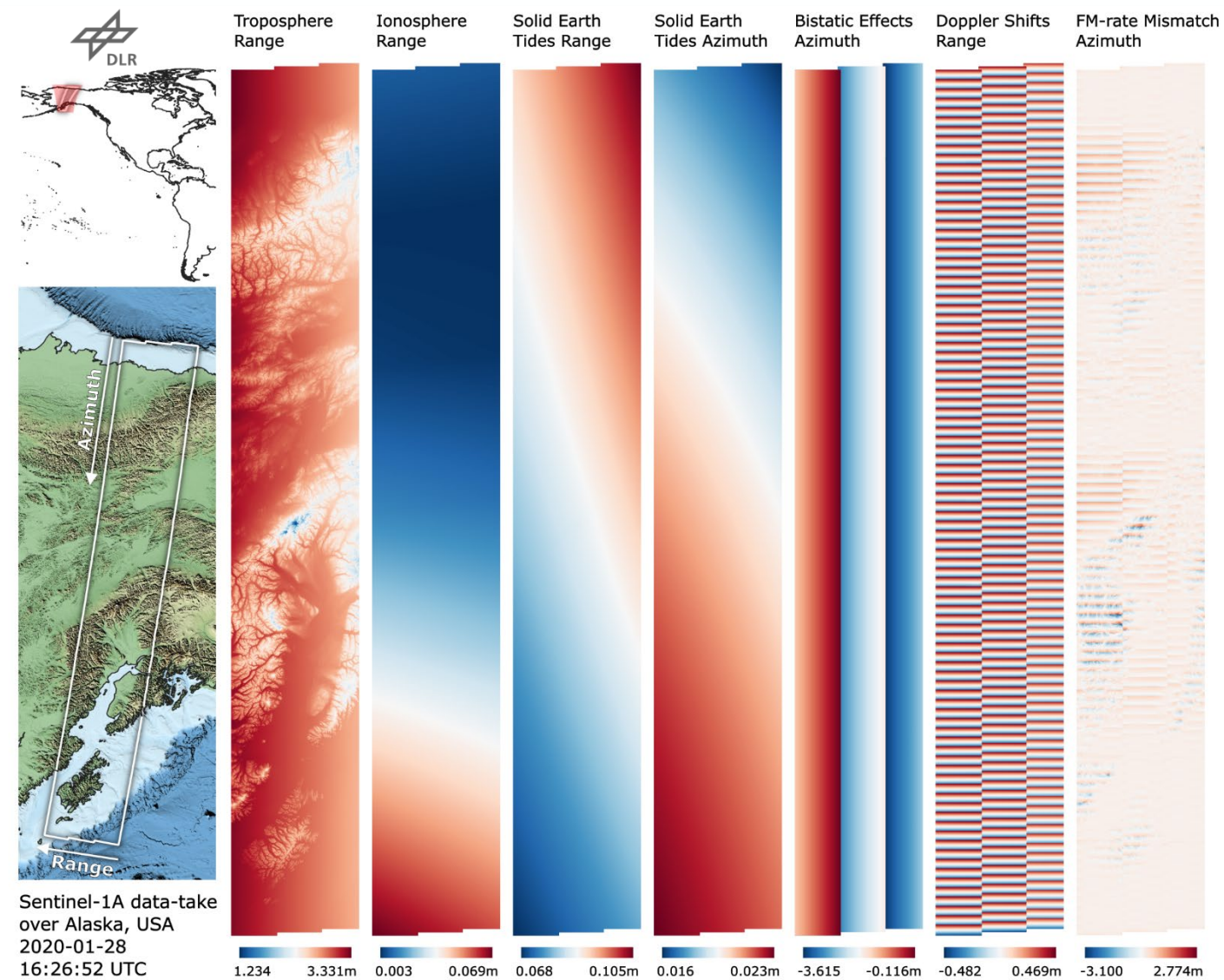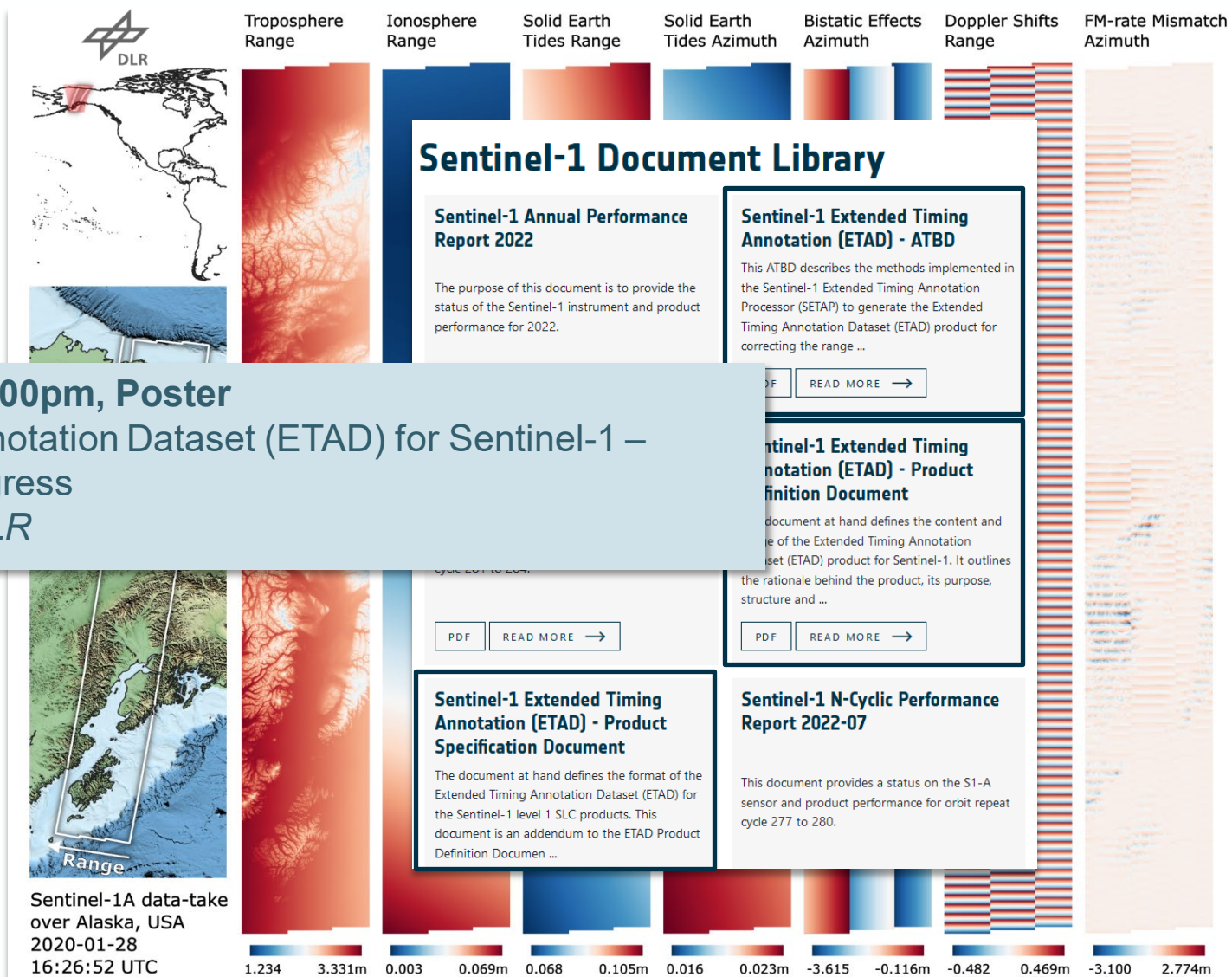| Troposphere Range	Ionosphere Range	Solid Earth Tides Range	Solid Earth Tides Azimuth	Bistatic Effects Azimuth	Doppler Shifts Range	FM-rate Mismatch Azimuth
1.234 3.331m	0.003 0.069m	0.068 0.105m	0.016 0.023m	-3.615 -0.116m	-0.482 0.469m	-3.100 2.774m

Extend Time Annotation Product (ETAD)

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R-5, R-7, R-8
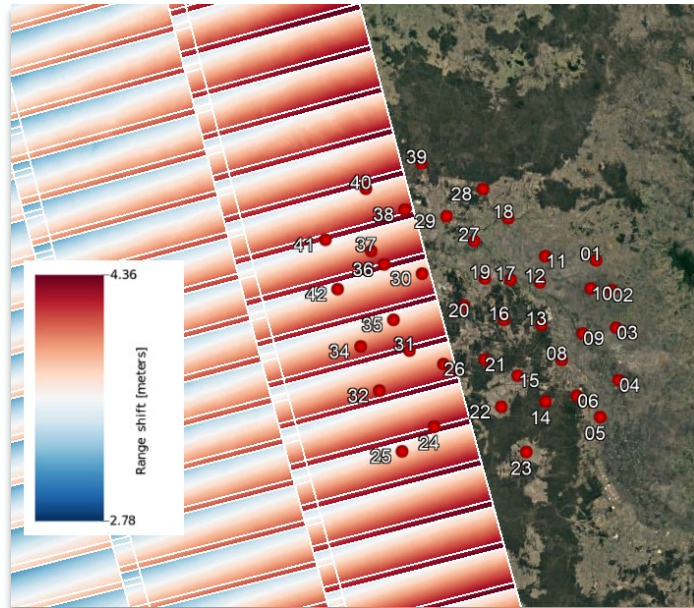ETAD, provision of data for co-registration support, e.g., geodetic layers

Time: Tuesday, 4:30pm-7:00pm, Poster
ESA's Extended Timing Annotation Dataset (ETAD) for Sentinel-1 –
Product Overview and Progress
Christoph Gisinger et al, DLR

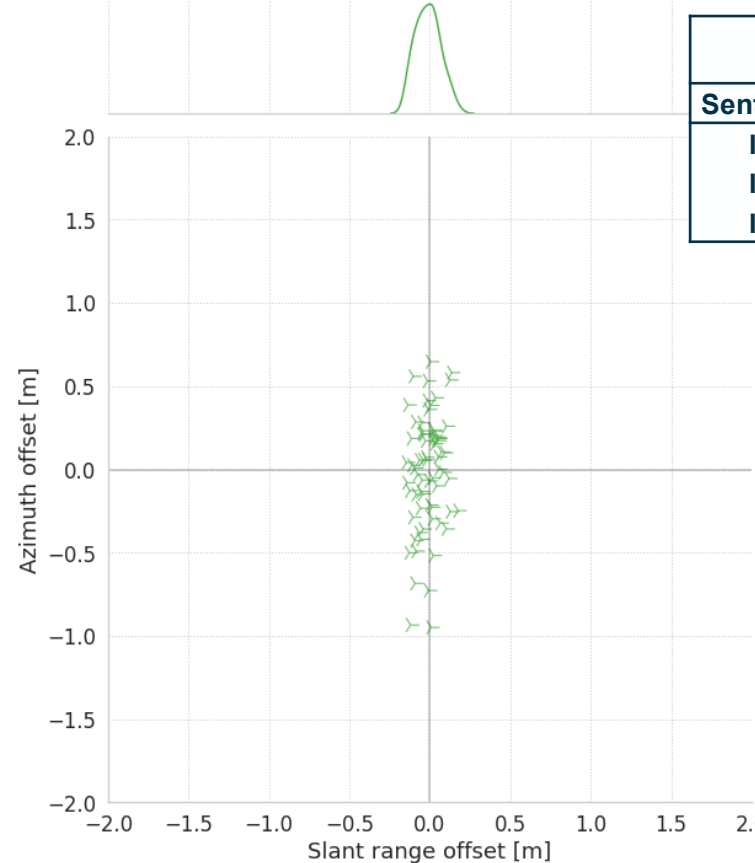Troposphere Range · Ionosphere Range · Solid Earth Tides Range · Solid Earth Tides Azimuth · Bistatic Effects Azimuth · Doppler Shifts Range · FM-rate Mismatch Azimuth

Sentinel-1A data-take over Alaska, USA 2020-01-28 16:26:52 UTC

1.234 3.331m   0.003 0.069m   0.068 0.105m   0.016 0.023m   -3.615 -0.116m   -0.482 0.469m   -3.100 2.774m

Sentinel-1 Document Library

Sentinel-1 Annual Performance Report 2022

The purpose of this document is to provide the status of the Sentinel-1 instrument and product performance for 2022.

Sentinel-1 Extended Timing Annotation (ETAD) - ATBD

This ATBD describes the methods implemented in the Sentinel-1 Extended Timing Annotation Processor (SETAP) to generate the Extended Timing Annotation Dataset (ETAD) product for correcting the range ...

Sentinel-1 Extended Timing Annotation (ETAD) - Product Definition Document

...document at hand defines the content and ... of the Extended Timing Annotation ...aset (ETAD) product for Sentinel-1. It outlines the rationale behind the product, its purpose, structure and ...

Sentinel-1 Extended Timing Annotation (ETAD) - Product Specification Document

The document at hand defines the format of the Extended Timing Annotation Dataset (ETAD) for the Sentinel-1 level 1 SLC products. This document is an addendum to the ETAD Product Definition Documen ...

Sentinel-1 N-Cyclic Performance Report 2022-07

This document provides a status on the S1-A sensor and product performance for orbit repeat cycle 277 to 280.

	Range ALE [m]	Azimuth ALE [m]
Sentinel-1B	-0.012 +/- 0.076	-0.012 +/- 0.344
IW-1	/	/
IW-2	/	/
IW-3	-0.012 +/- 0.076	-0.012 +/- 0.344

ETAD validation: analysis over corner reflectors

Extend Time Annotation Product (ETAD)

- Test pilot was carried out in 2022 with expert users for independent validation (focus on speckle tracking and interferometry)

- Continuation activities

  - New layers

    - Ocean loading

    - Pole tides

    - Ionospheric

  - InSAR

    - Support to h...

    - New tropos...

  - NRT aspects

  - Starting of preparation for future missions (L-band)

Winter 2023

...tracking - C3S)

Winter 2024 (TBC)

New layers integrated (including extended support to InSAR, EGMS)

> **Time: Monday, 4:10pm - 4:30pm, Location: Auditorium I**
> Interferometric Phase Corrections Based On ESA's Extended Timing Annotation Dataset (ETAD) For Sentinel-1
> *Victor Diego Navarro Sanchez et al, DLR*

> **Time: Monday, 4:30pm - 4:50pm, Location: Auditorium I**
> Impact of ETAD-like corrections on OPERA Coregistered Single Look Complex products from Sentinel-1 data
> *Heresh Fattahi et al, JPL*

> **Time: Monday, 4:50pm - 5:10pm, Location: Auditorium I**
> Exploiting ETAD Data For Estimating And Filtering Out The Atmospheric Phase Screen Component From Medium/High Resolution DInSAR Products
> *Ivana Zinno et al, CNR-IREA*

Extend Time Annotation Product (ETAD)

- Test pilot was carried out in 2022 with expert users for independent validation (focus on speckle tracking and interferometry)

- Continuation activities in place with focus on
  - New layers
    - Ocean loading
    - Pole tides
    - Ionospheric
  - InSAR
    - Support to h
    - New troposp
  - NRT aspects
  - Starting of preparation for future missions (L-band)

Winter 2023

Products routinely disseminated (ready to tracking, C3S)

Winter 2024 (TBC)

New layers integrated (including extended support to InSAR, EGMS)

Thank you to pilot participants!

Time: Monday, 4:30pm - 4:50pm, Location: Auditorium I
Impact of ETAD-like corrections on OPERA Coregistered Single Look Complex products from Sentinel-1 data
Heresh Fattahi et al, JPL

Time: Monday, 4:50pm - 5:10pm, Location: Auditorium I
Exploiting ETAD Data For Estimating And Filtering Out The Atmospheric Phase Screen Component From Medium/High Resolution DInSAR Products
*Ivana Zinno et al, CNR-IREA*

User support: data processed without orbit

- From March to December 2021, due to an interface anomaly, all L1 has been processed without POD orbits (see here)

- Recently, the MPC has been contacted to review the analysis, given user evidence from speckle tracking timeseries

- MPC performed extensive complementary analysis, including analysis of radiometry and FM rate and interferometric assessment between data processed with and without orbits

- Analysis supports previous conclusion of no considerable degradation in the data

Burst amplitude and phase differences
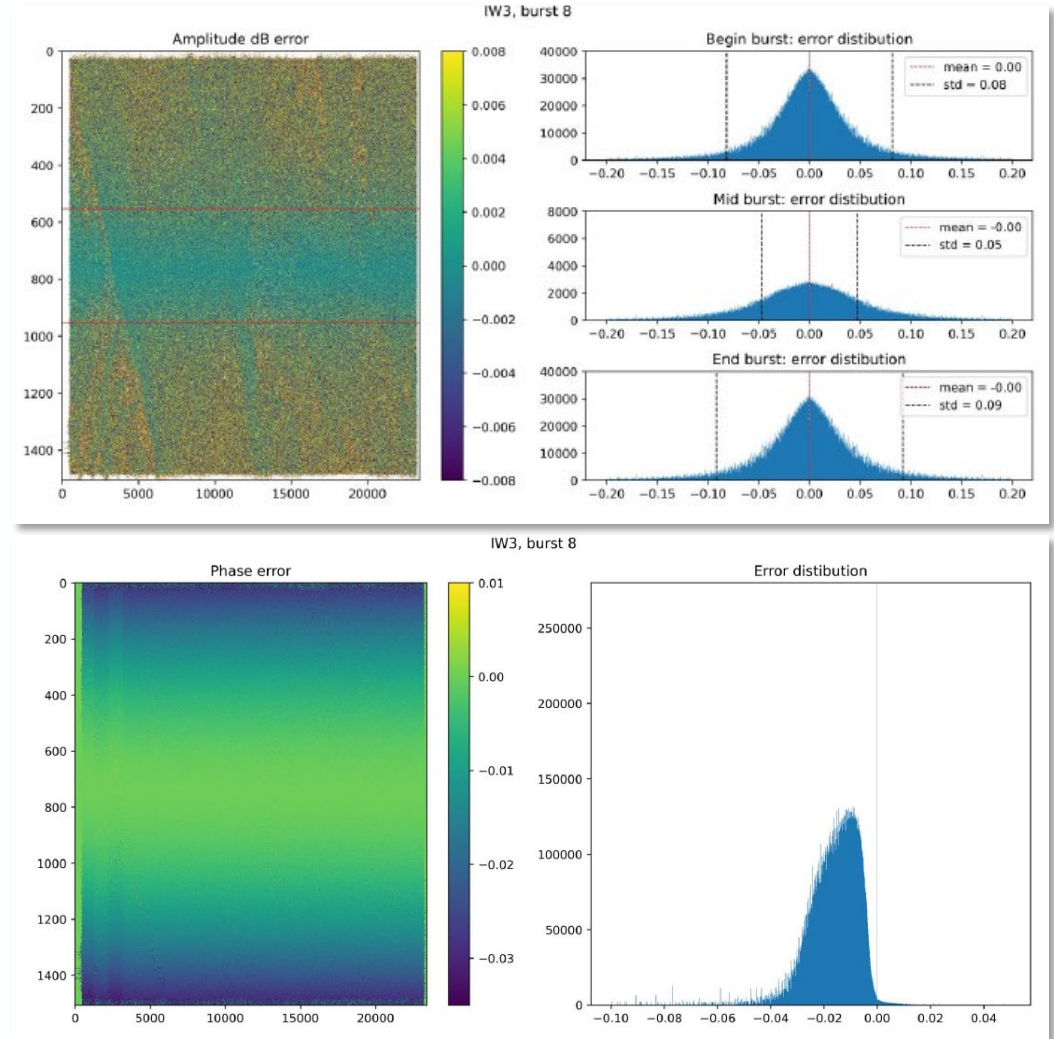
Outline

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- ❑ **Highlights on on-going activities**

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R-1, R-26
Provision of consistent interferogram, fading signal
*R-2
SLC as the main ESA "ingredient"

Time: Wednesday, 9:00am-10:40am, Location: Auditorium I
Towards a Universally Applicable Phase Bias Correction for Short-Term
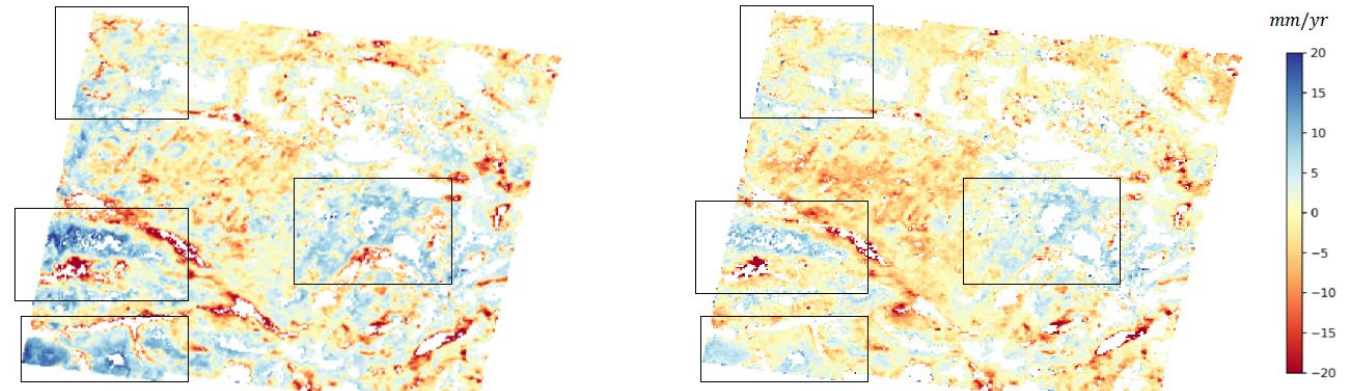Multi-Looked Interferograms: Challenges and Progress
Yasser Maghsoudi et al, University of Leeds

Maghsoudi et al. (2022)

UNIVERSITY OF LEEDS

Results – velocities

Before correction

After correction

→ THE EUROPEAN SPACE AGENCY

Activities related to Fringe 21 recommendations

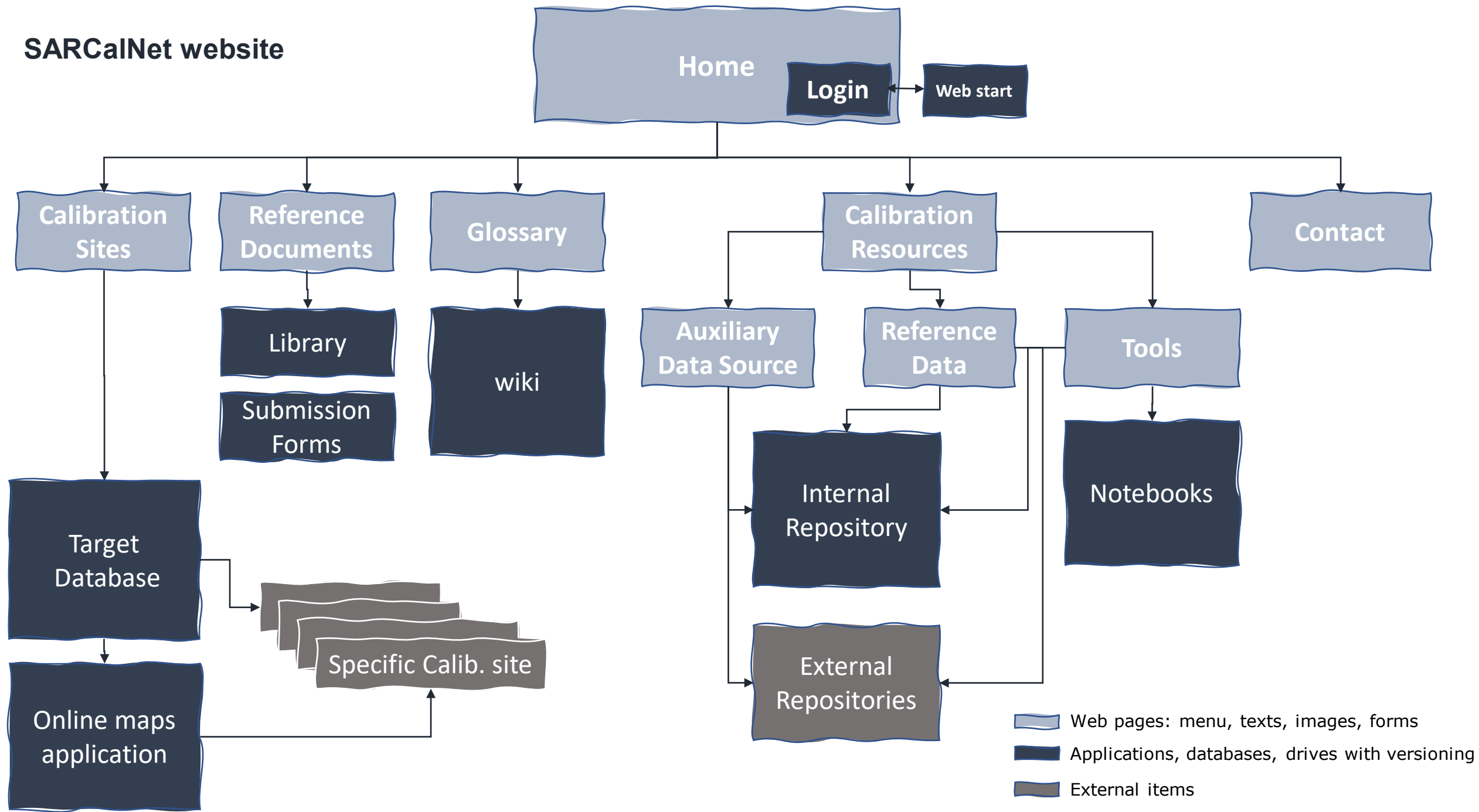**R-46**
ESA fostering mechanism for acknowledgement of sites with CRs/Transponders and their networking

SARCalNet website

- Home
  - Login → Web start
  - Calibration Sites
    - Target Database → Specific Calib. site
      - Online maps application → Specific Calib. site
  - Reference Documents
    - Library
    - Submission Forms
  - Glossary
    - wiki
  - Calibration Resources
    - Auxiliary Data Source
    - Reference Data
      - Internal Repository
      - External Repositories
    - Tools
      - Notebooks

Legend:
- Web pages: menu, texts, images, forms
- Applications, databases, drives with versioning
- External items

Thank you!

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