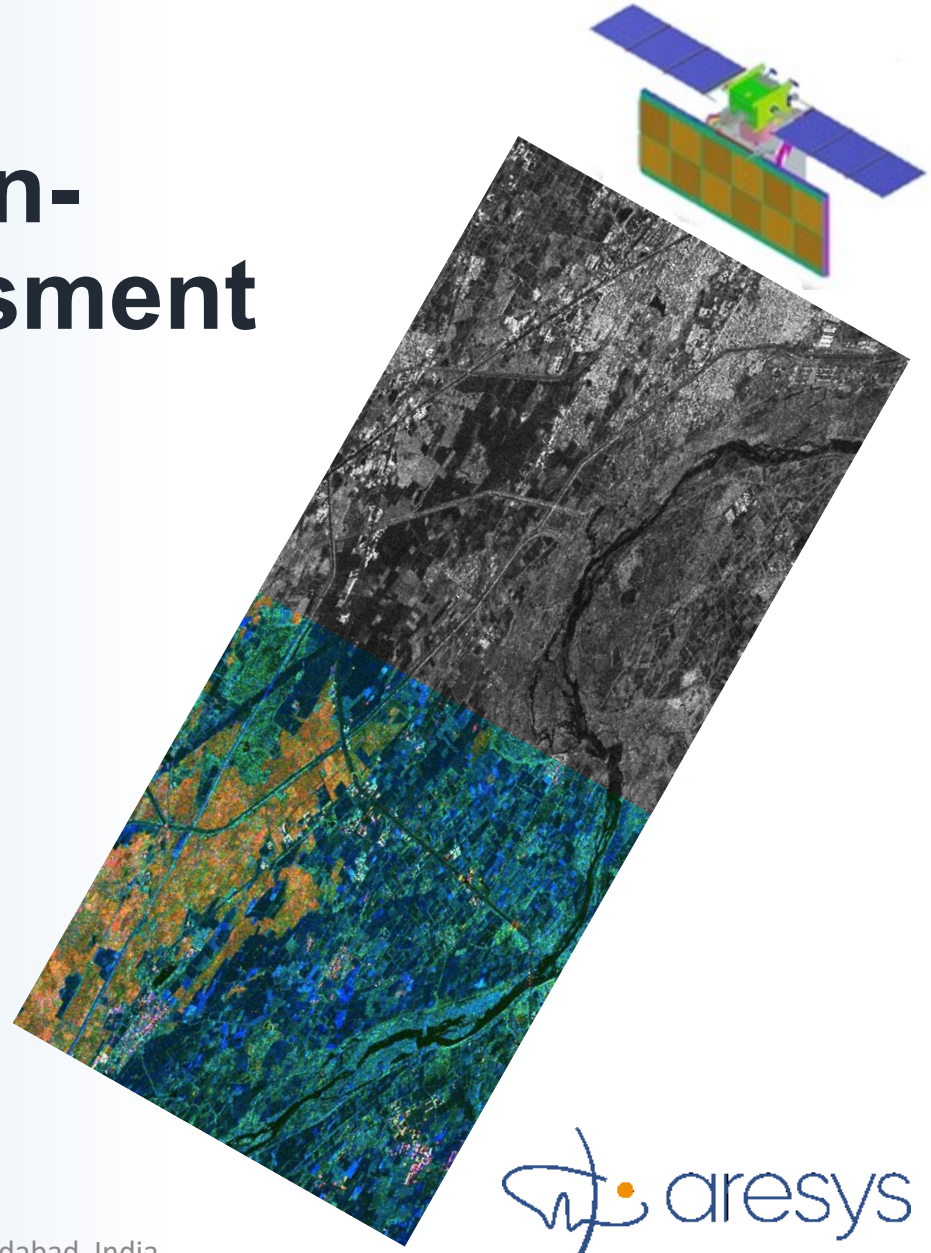
# SAR Calibration Toolbox: an open-source tool for the quality assessment of SAR data



Andrea Recchia[(1)], Giorgio Parma[(1)], Matteo Aletti[(1)], Riccardo Piantanida[(1)], **Beatrice Mai[(1)]**, Leonardo De Laurentiis[(2)], Clement Albinet[(2)], Muriel Pinheiro[(2)], Antonio Valentino[(3)]

[(1)]ARESYS, [(2)]ESA, [(3)]RHEA Group

Contact: andrea.recchia@aresys.it

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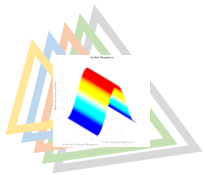
Meeting: CEOS 2024, Ahmedabad
Session: 5: Innovative concepts and processing algorithms

# Outline

- Earthnet Data Assessment Project
- SAR missions' quality assessment
- SAR Calibration Toolbox
- EOS-04 assessment
- Conclusion



# Earthnet Data Assessment Project

- The Earthnet Data Assessment Project (EDAP+) is responsible for assessing the quality and suitability of candidate missions being considered for the Earthnet Third Party Missions (TPM)
- The key objective of ESA's EDAP is to take full advantage of the increased range of available data from non-ESA operated missions and to perform an early data assessment for various missions falling into one of these following instrument domains:
  - VHR and HR Optical Missions
  - SAR missions
  - Atmospheric Missions
  - AIS & RF Missions

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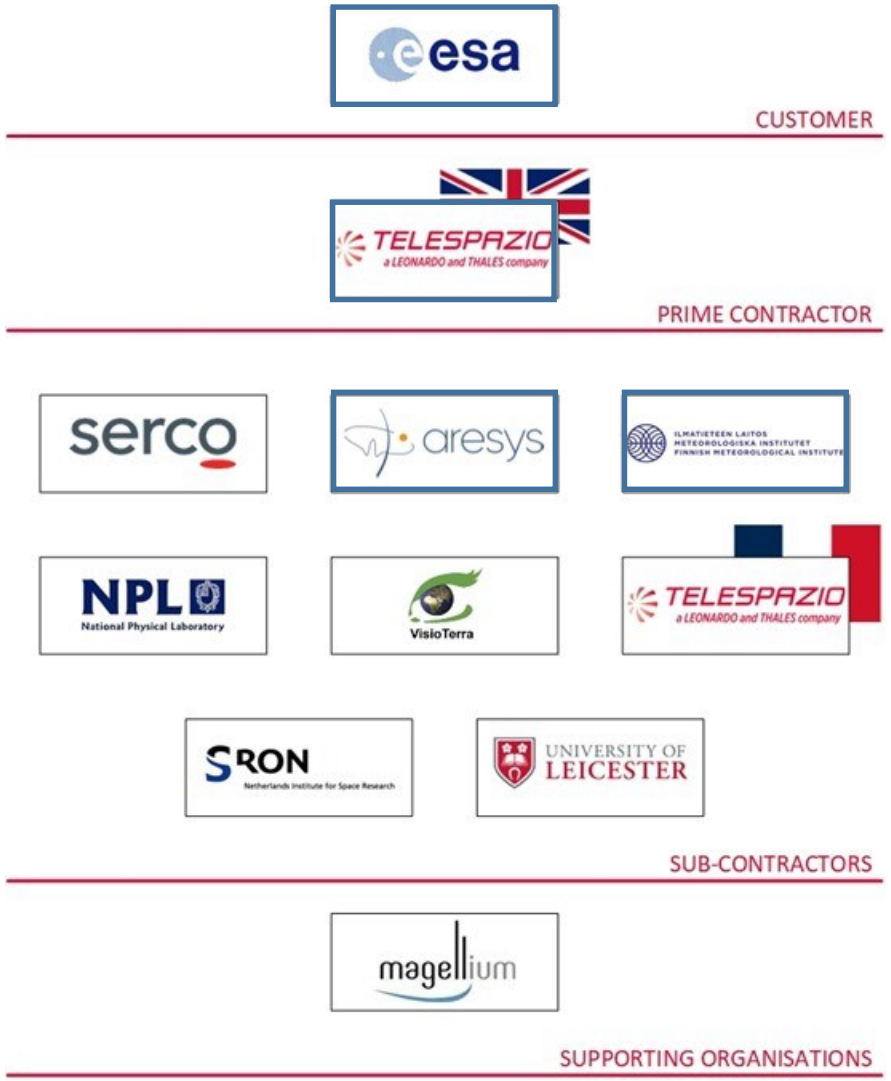
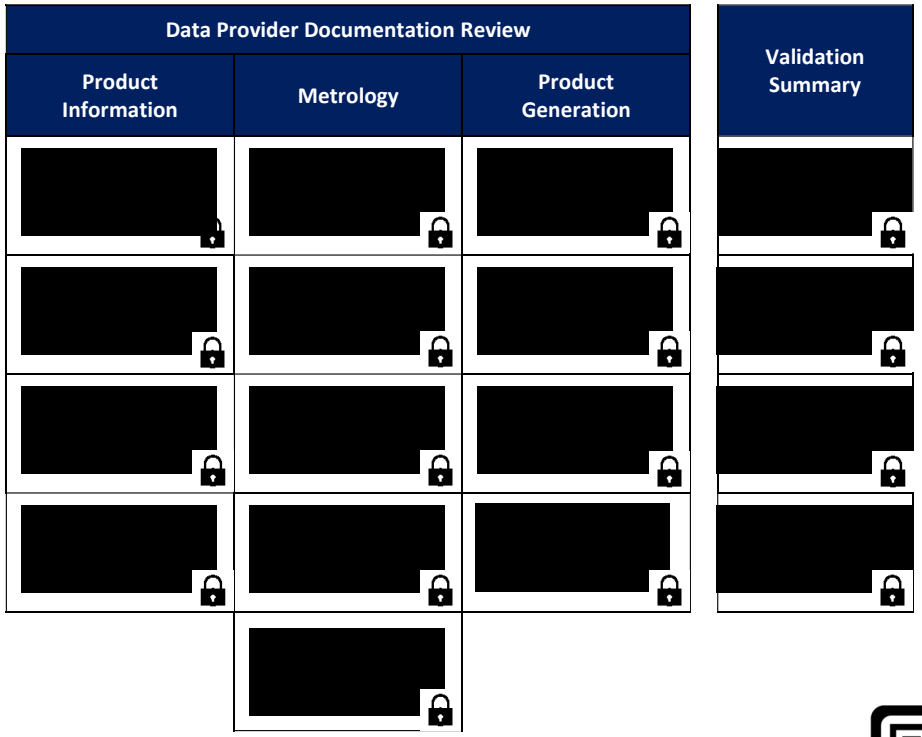


# Mission Quality Assessment Matrix

- The mission quality assessment is based on specific guidelines and cover the following aspects:
  - Mission documentation review
  - Independent data quality validation
- The results of the assessment are reported in dedicated mission reports that are published on the EDAP website
- The quality assessment follows a set of 'best practice' guidelines (available on EDAP website) aligned to the principles of QA4EO Framework
- The Mission Quality Assessment Matrix provides in a compact form the results of the performed validation activities.

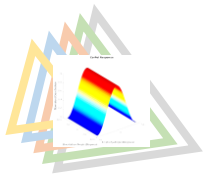



EDAP+

# SAR Missions Quality Assessment

- The mission documentation review is aimed at evaluating the quality of the documentation available to the users
- SAR products availability and accessibility to users is also assessed
- Independent SAR data quality assessment is performed on a set of the third-party SAR mission datasets over calibration sites
- Tools used for SAR data quality assessment:
  - ESA Snap Toolbox (if applicable)
  - **Aresys SAR Calibration Toolbox**
  - Telespazio KARIOS tool for ARD data assessment

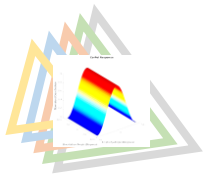
| Quality parameter | Metric | Data type | Cal. Sites |
|---|---|---|---|
| IRF | Spatial resolution | Point Target | Mission dedicated sites<br>Rosamond Corner Reflector Array (California)<br>Surat Basin (Australia) |
| | Peak-to-Side Lobe ratio | Point Target | |
| | Integrated Side Lobe ratio | Point Target | |
| Geometry | Localization | Point Target | |
| Radiometry | Calibration constant | Point Target | |
| | Elevation Antenna Pattern | Rain Forest | Rain Forest: Amazon, Congo |
| | Azimuth scalloping | Rain Forest | |
| | Beam-to-beam offset | Rain Forest | |
| | Polarimetric imbalance | Rain Forest | |
| | ENL | Rain Forest | |
| | Noise level | Low backscatter | Doldrums, Lakes, Deserts |



# SAR Calibration Toolbox Overview

- SCT is an open-source tool for quality assessment and calibration of SAR products developed under the framework of EDAP+ and SAR MPC projects
- Source code publicly available on GitHub: https://github.com/aresys-srl/sct
- Developed as a full-fledged Python library with modular design and modular dependencies
- Comes with a Command Line Interface (CLI) Tool to be used from terminal
- Implemented features:
  - Point Target Analysis
  - Radiometric Profiles: Rain Forest and NESZ
  - Interferometric Coherence Analysis

SCT GitHub

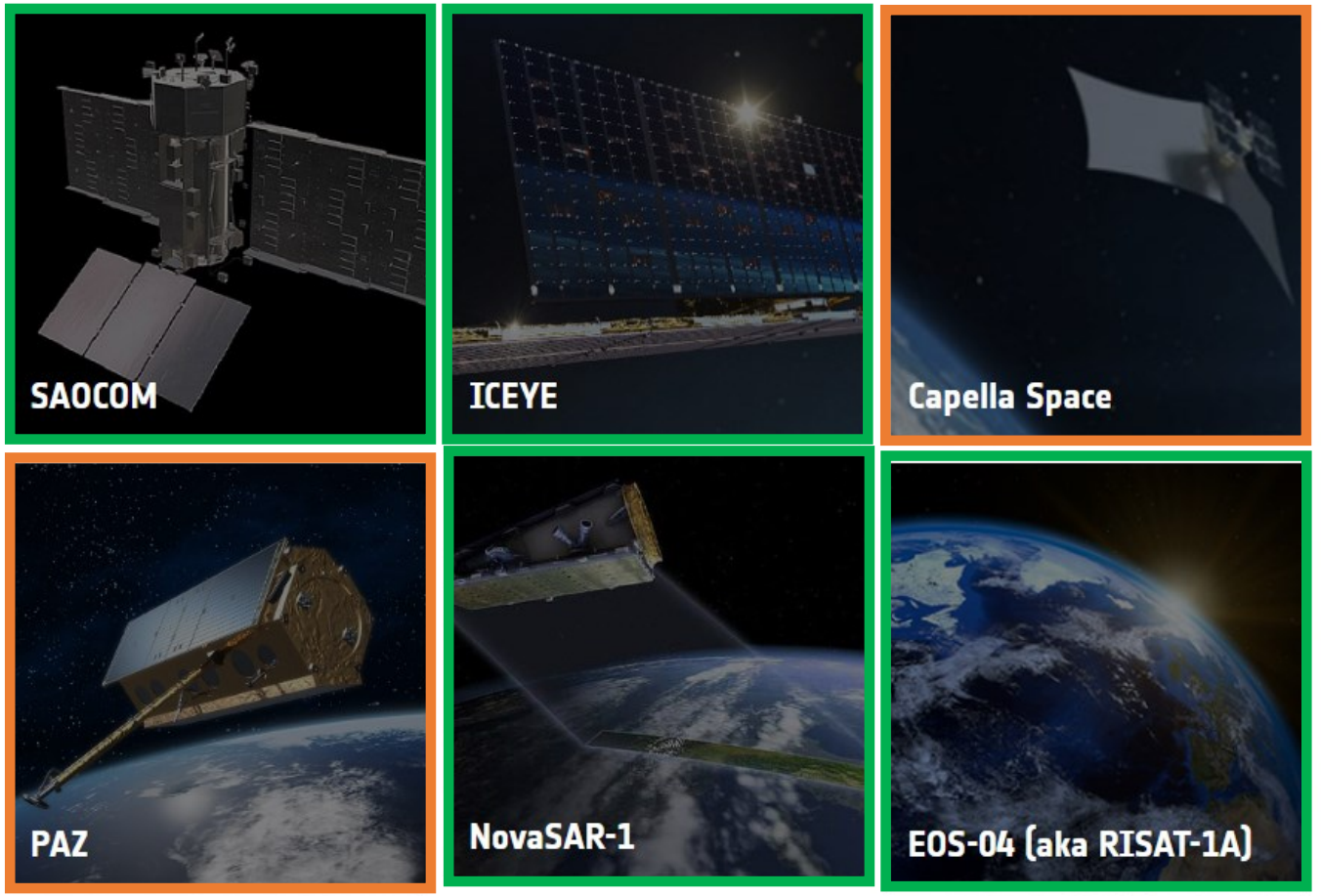


# SAR Calibration Toolbox Overview

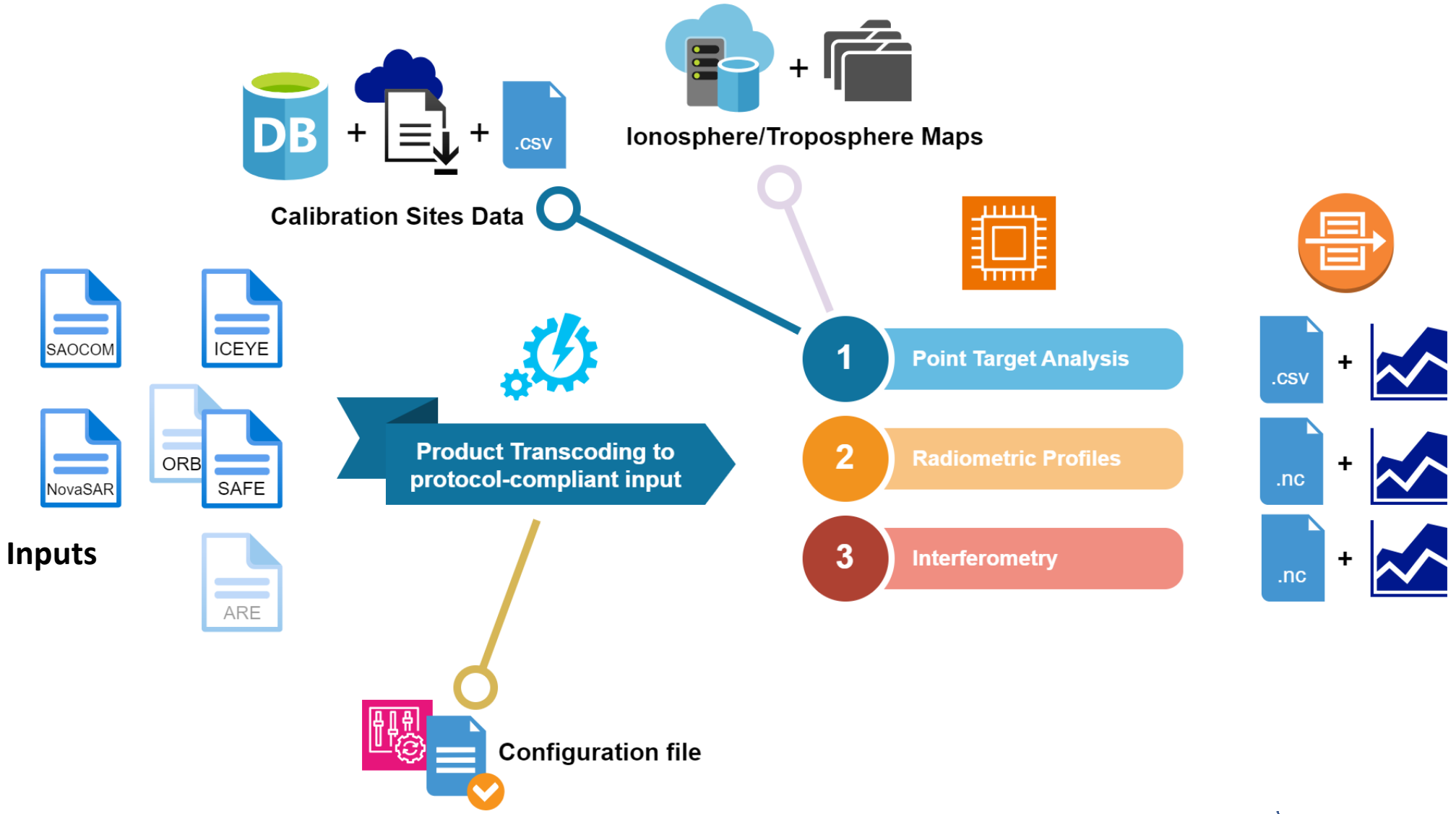
- High level of customization for each analysis: high- and low-level parameters tuning, additional options and secondary utilities
- Multi-sensor and mission support: Sentinel-1, ICEYE, NovaSAR-1, EOS-04, SAOCOM
- Full documentation of algorithm implementation, functionalities and API interfaces
- Easily extensible for other product formats and missions
- Installation using pip with local cloned repo for each dependency in strict order as reported in README file

**Format fully compatible with SCT tools (Sentinel-1 also included)**

**Format conversion needed before SCT analysis**



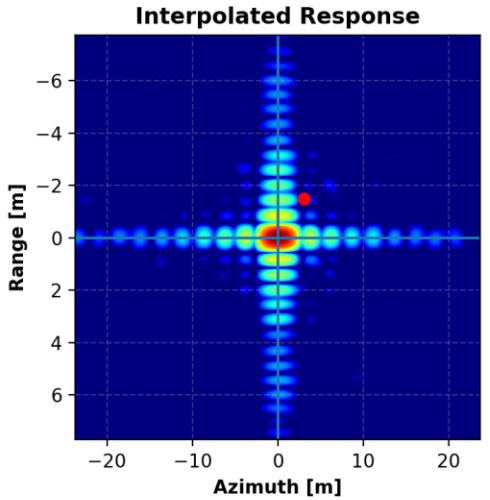
# SCT Architecture Overview



# Point Target Analysis

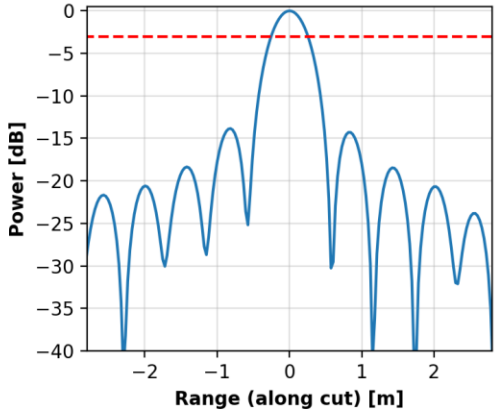
- Full Point Target Data Analysis: batch analysis on input point target locations related to the given SAR product
- IRF analysis: PSLR, ISLR, SSLR (for each direction and 2D)
- RCS analysis: RCS, RCS Error, SCR, Clutter
- Localization analysis: Range ALE, Azimuth ALE, Ground Range ALE
- Several other output computed quantities can be found in the output .csv file
- Fully customizable parameters
- CLI tool available
- Graphical output available

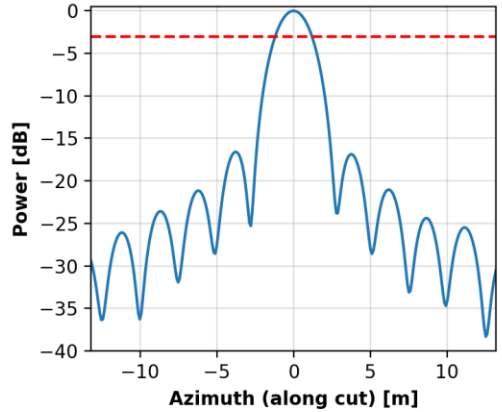
**target_ROS11CR_S1_polarization_VV_slc_b0 IRF Analysis**

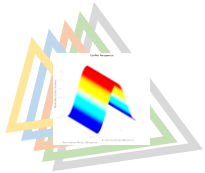



| | Range | Azimuth |
|---|---|---|
| Resolution [m] | 0.50866 | 2.3952 |
| PSLR [dB] | -13.83915 | -16.58905 |
| ISLR [dB] | -10.64897 | -13.70601 |

| | Localization Error |
|---|---|
| Slant Range [m] | -1.49105 |
| Ground Range [m] | -5.87841 |
| Azimuth [m] | 3.07039 |

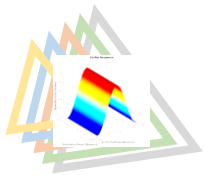


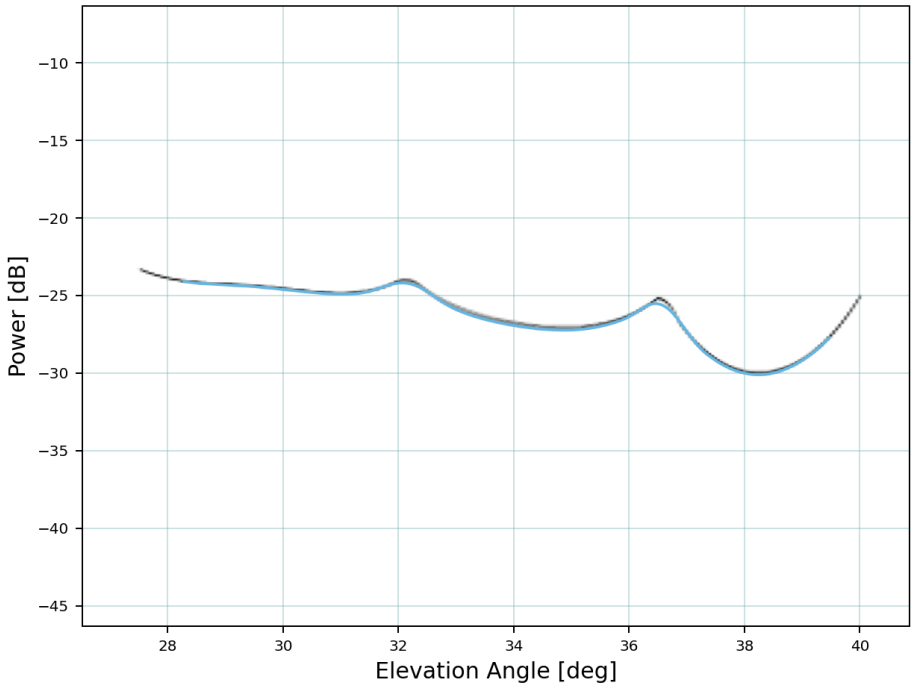
# Geocoding Perturbations Features for Point Target Analysis

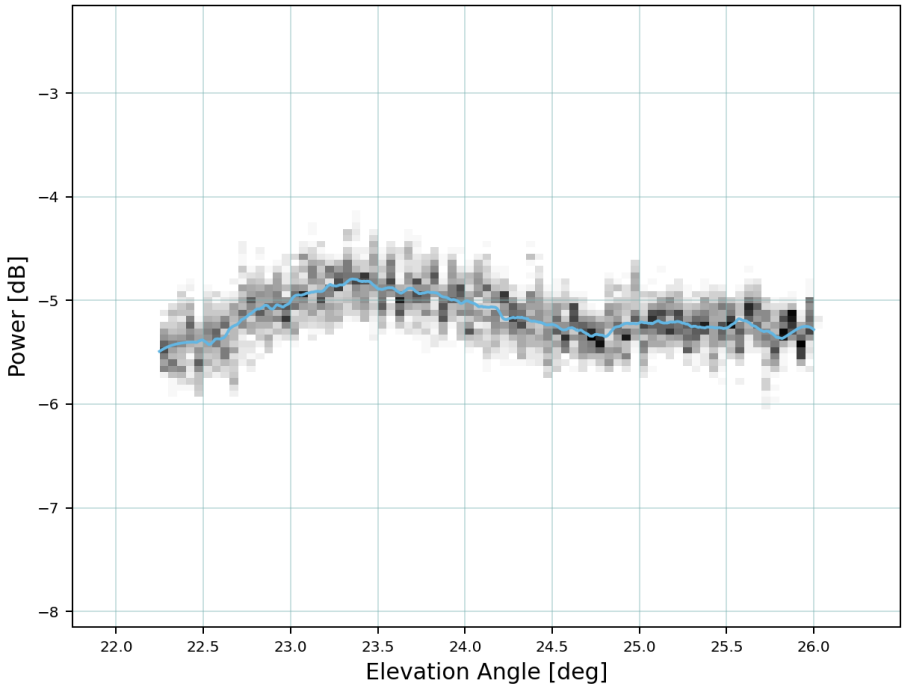
- To enhance the geocoding accuracy and mitigate localization errors related to external influences for Point Target Analysis, several optional corrections have been implemented:
- **Solid Earth Tides Displacement**: computing solid tides for a specific ground point at a given time
- **Plate Tectonics Displacement**: computing the plate tectonic movement using provided drift velocities or an internal model
- **Ionospheric Delay**: computing signal delay due to ionospheric effects from external TEC maps
- **Tropospheric Delay**: computing signal delay due to tropospheric effects from external maps
- **Sensor specific processing corrections**: currently Sentinel-1 only
- **Sentinel-1 ETAD Range and Azimuth corrections**: if an ETAD product is provided, range and azimuth corrections can be applied



# Radiometric Analysis

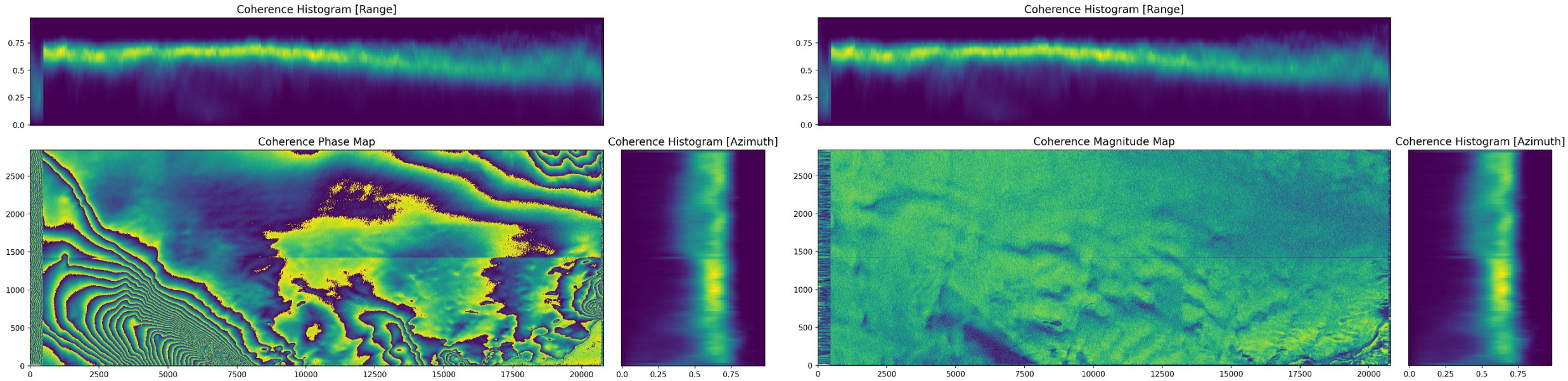
- Radiometric Analyses: NESZ, Average Elevation Profiles, Scalloping Profiles
- Computed profiles saved in NetCDF output files
- Fully customizable parameters
- CLI tool available
- Graphical output available



# Interferometric Coherence Analysis

- Interferometric Analyses: coherence map from two co-registered products or from single interferogram product
- Computing and displaying coherence matrix and histograms both phase and magnitude
- Fully customizable parameters
- CLI tool available
- Graphical output available



# Usage example

Every feature can be accessed both using the python library API or via CLI dedicated commands.

Usage as python library:

```python
from pathlib import Path
from sct.analyses import point_target_analysis as pta

product_path = "path_to_SAR_product_to_be_analyzed"
point_target_locations_file = "path_to_point_targets_location_file"
output_directory = "path_to_directory_where_to_save_output"

# executing point target analysis
out, _ = pta.point_target_analysis_with_corrections(
    product_path=product_path,
    external_target_source=point_target_locations_file,
)
# saving results
out.to_csv(Path(output_directory).joinpath("point_target_analysis_results.csv"), index=False)

```

Usage as CLI tool:

```
$ sct -p "path_to_product" -pt "path_to_point_targets_locations_file" -out "path_to_output_directory" --graphs
```

# EOS-04

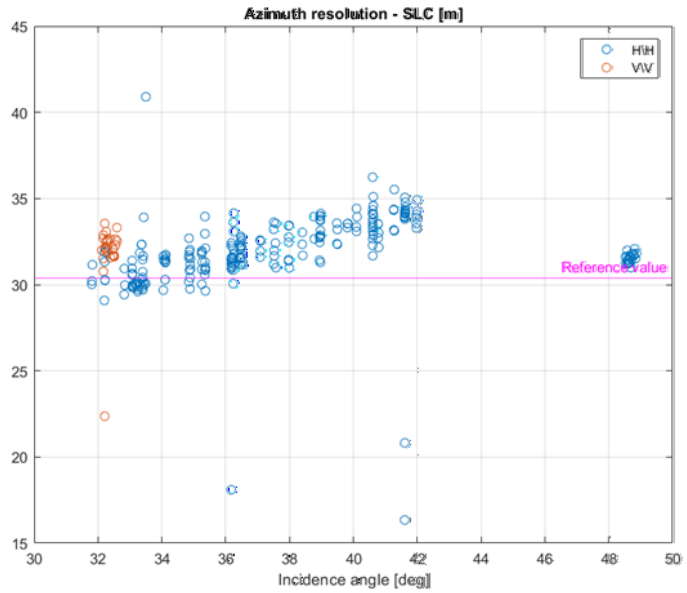
| Parameters | Specifications |
|---|---|
| Altitude | 524.87 km |
| Orbit | Sun synchronous (6 AM - descending / 6 PM equatorial crossing) |
| Frequency | 5.4 GHz + 37.5 MHz |
| Polarization Combination | Single / Dual / Full-pol /Hybrid circular polarimetry (Transmit circular, receive linear) |
| Average DC Input Power | 3.8 kW |
| Pulse width | 5 µs to 25 µs |
| Antenna Roll Bias (deg) | ± 36° |
| Range Coverage (km) | 107-659 (either side of flight track) |
| Look Angle (deg) | 11.5-49.6 |
| Incidence Angle (deg) | 12.4-55.5 |
| Acquisition Modes | Spotlight: 1 m resolution<br>Stripmap: 3 m resolution<br>ScanSAR: 30-50 m resolution |

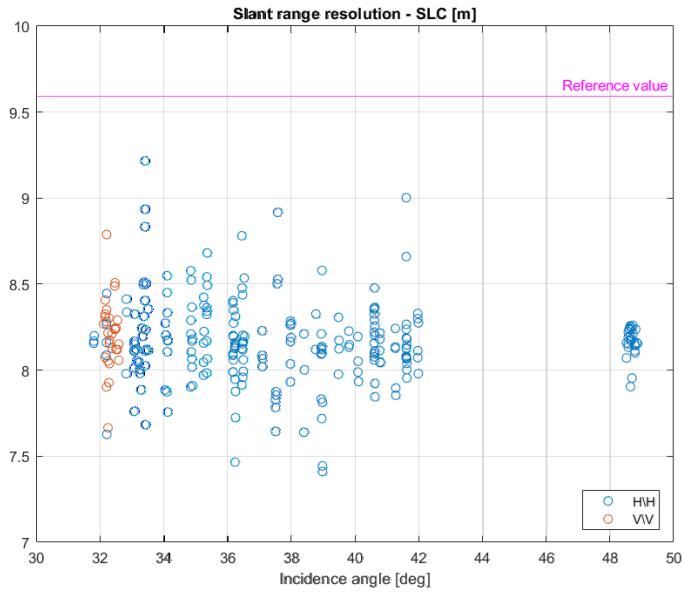
**EOS-04 image over Rosamond target array Medium Resolution ScanSAR Mode (MRS): 33 m resolution, 160 km swath**

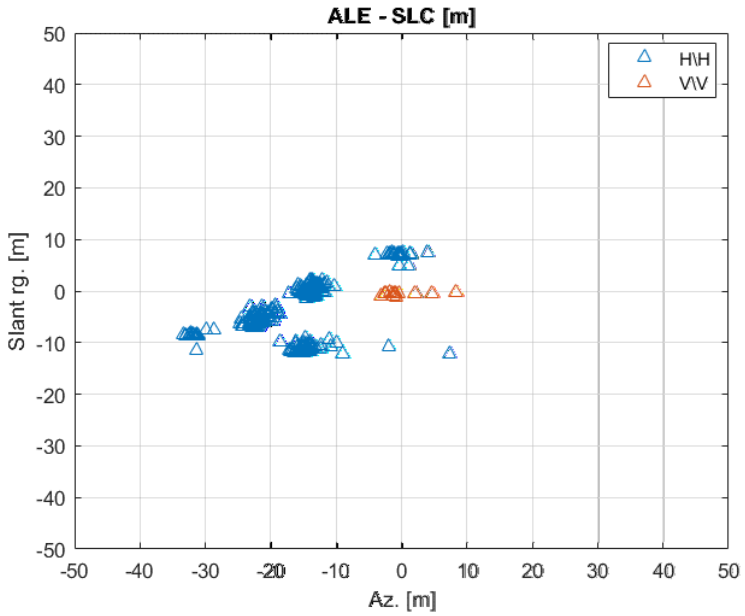
# EOS-04: point target analysis

- Point target parameters from Rosamond and Surat Basin calibration sites aligned with mission requirements/specifications
- Next version of GRD products will include a higher order slant to ground polynomial allowing a better geolocation

| | Product | Az. Res [m] | Slant rg. Res [m] | ALE: azimuth [m] | ALE: slant rg. [m] | PSLR range [dB] | PSLR azimuth [dB] | ISLR range [dB] | ISLR azimuth [dB] |
|---|---|---|---|---|---|---|---|---|---|
| ROSAMOND | 244692311 | 31.525 | 8.164 | -37.904 | -7.408 | -20.536 | -12.749 | -15.538 | -9.897 |
| | 244692321 | 31.147 | 8.173 | 7.010 | 1.955 | -20.154 | -12.162 | -15.474 | -8.642 |
| | 244692341 | 31.880 | 8.209 | 5.071 | 9.131 | -17.017 | -12.286 | -11.012 | -8.397 |
| SURAT BASIN | 244692411 | 31.119 | 8.160 | -13.957 | -10.935 | -15.417 | -11.418 | -9.001 | -6.858 |
| | 245917611 | 32.389 | 8.116 | -13.758 | 0.363 | -16.545 | -12.137 | -9.965 | -7.708 |
| | 246069011 | 32.368 | 8.211 | -21.854 | -5.323 | -16.774 | -12.246 | -10.554 | -7.777 |

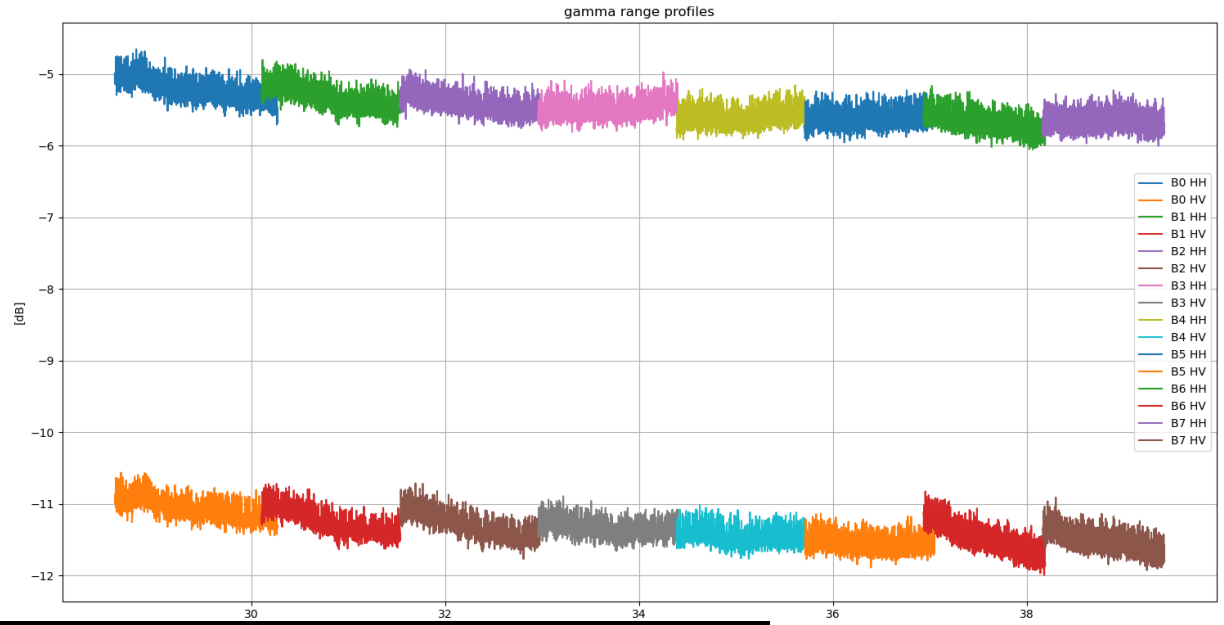


# EOS-04: distributed target analysis

**SLC**

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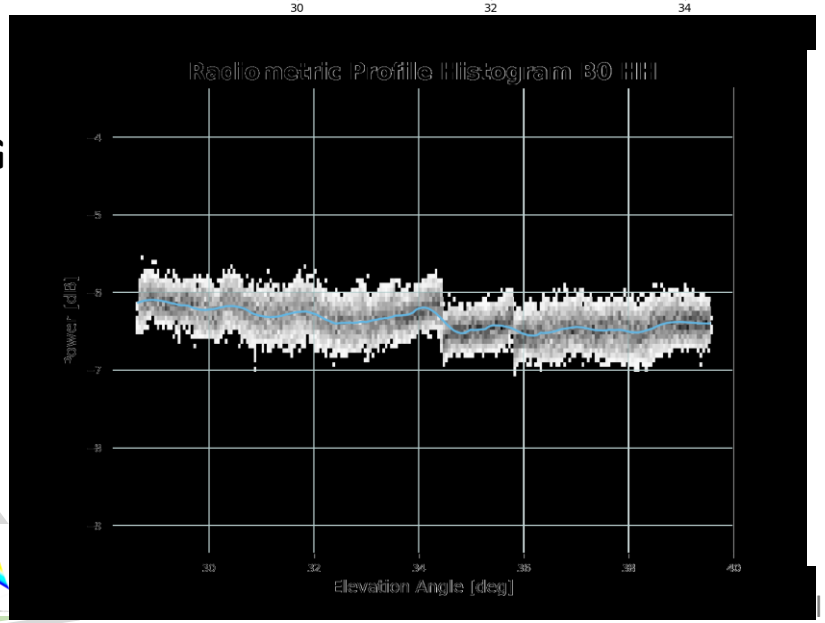
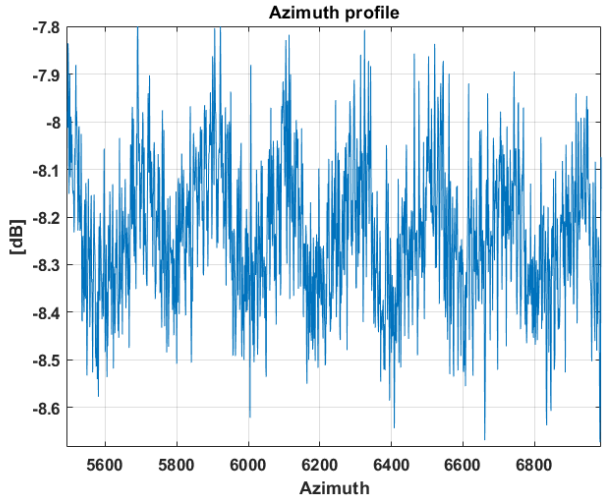
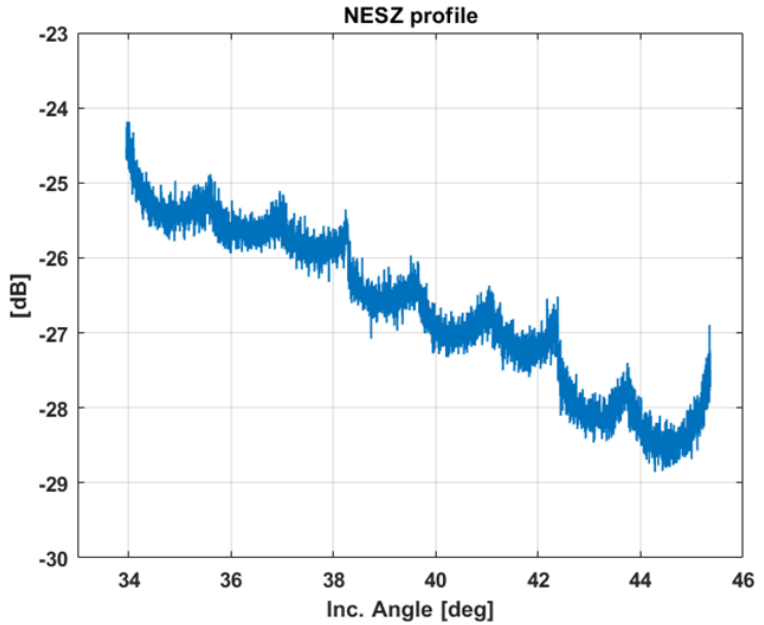



- Radiometric profiles from Rain Forest data are quite flat but some small radiometric jumps and residual slopes can be observed both in SLC and GRD data
- Small residual azimuth scalloping is observed
- NESZ level is good and close to S-1 level



# EOS-04 assessment results

| Data Provider Documentation Review | | |
|---|---|---|
| **Product Information** | **Metrology** | **Product Generation** |
| Product Details | Sensor Calibration & Characterisation 🔒 | Calibration Algorithm |
| Availability & Accessibility | Geometric Calibration & Characterisation 🔒 | Geometric Processing |
| Product Format, Flags & Metadata | Metrological Traceability Documentation | Mission-Specific Processing |
| User Documentation | Uncertainty Characterisation | |
| | Ancillary Data | |

| Validation Summary |
|---|
| Measurement Validation Method |
| Measurement Validation Results Compliance |
| Geometric Validation Method |
| Geometric Validation Results Compliance |

| Key |
|---|
| Not Assessed |
| Not Assessable |
| Basic |
| Good |
| Excellent |
| Ideal |
| 🔒 Not Public |

- Data quality is good, in line with mission specifications
- A few data issues have been reported in the EDAP TN and will be solved in the next versions of EOS-04 products
- Documentation is fine but a few more details on mission and products format could be useful
- The overall assessment is good, new analyses could be performed on future products' versions

# Conclusion

- The SAR missions' quality assessment activities in the framework of the EDAP+ project have been presented
- The open-source SAR Calibration Toolbox was developed in the framework of the EDAP (an SAR MPC) projects to provide to SAR data users a multi-mission general purpose SAR calibration tool
- SCT has been designed to allow for easy integration of new analyses and extension to new SAR missions
- Sample results of SCT tool on EOS-04 data, obtained in the framework of the EDAP+ assessment, have been presented.
- New SCT evolutions (design, functionalities and supported missions) are expected in the future

SCT GitHub

EDAP+