aresys
Advancing remote sensing

Results of the SAOCOM Commissioning Phase independent Cal/Val activities

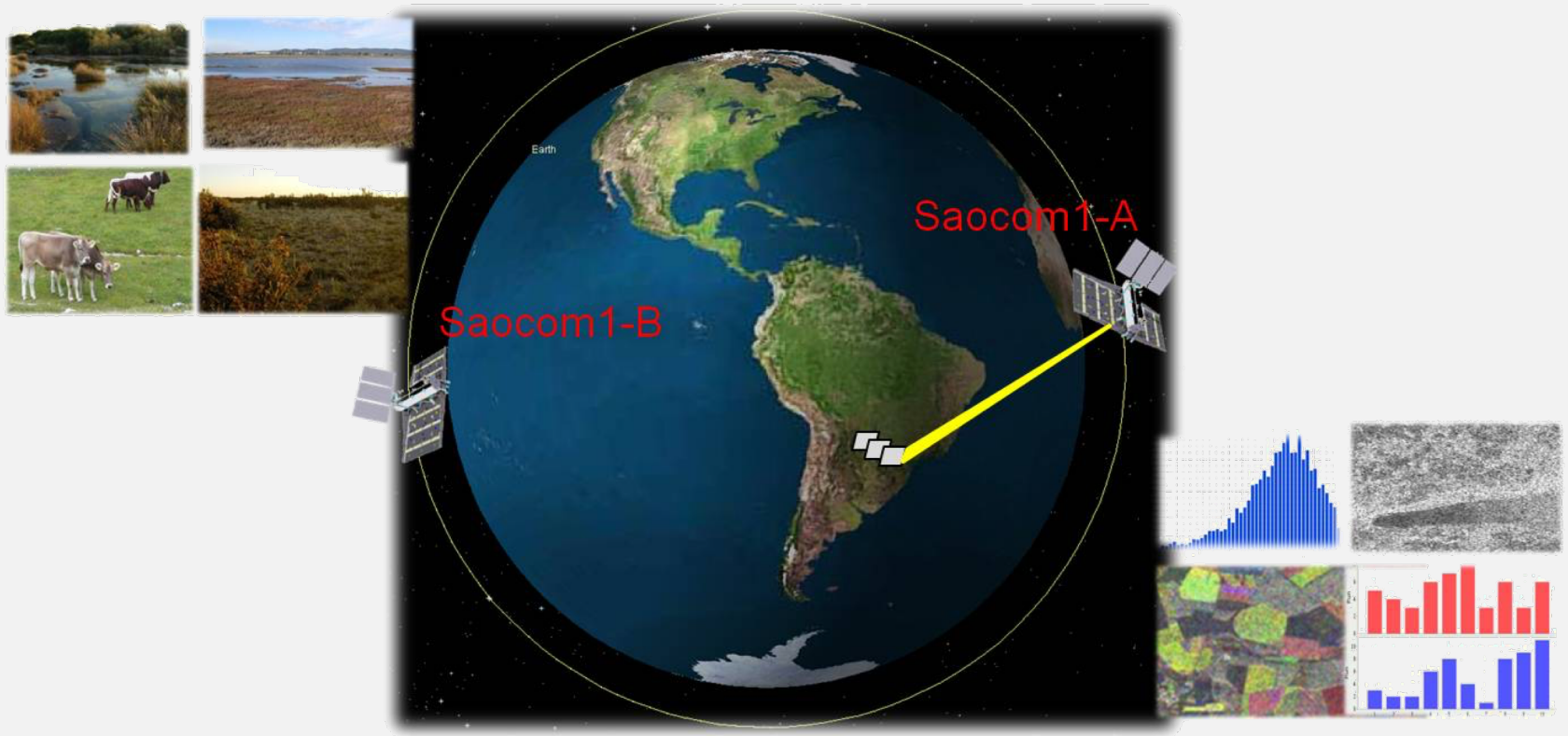
VENUE:	CEOS SAR Workshop, ESRIN, 18th-22nd November 2019
SESION:	Calibration Techniques #1
AUTHORS:	Andrea Recchia1, Davide Giudici, Simone Mancon, Antonio Valentino, Martin Steinisch

Outline

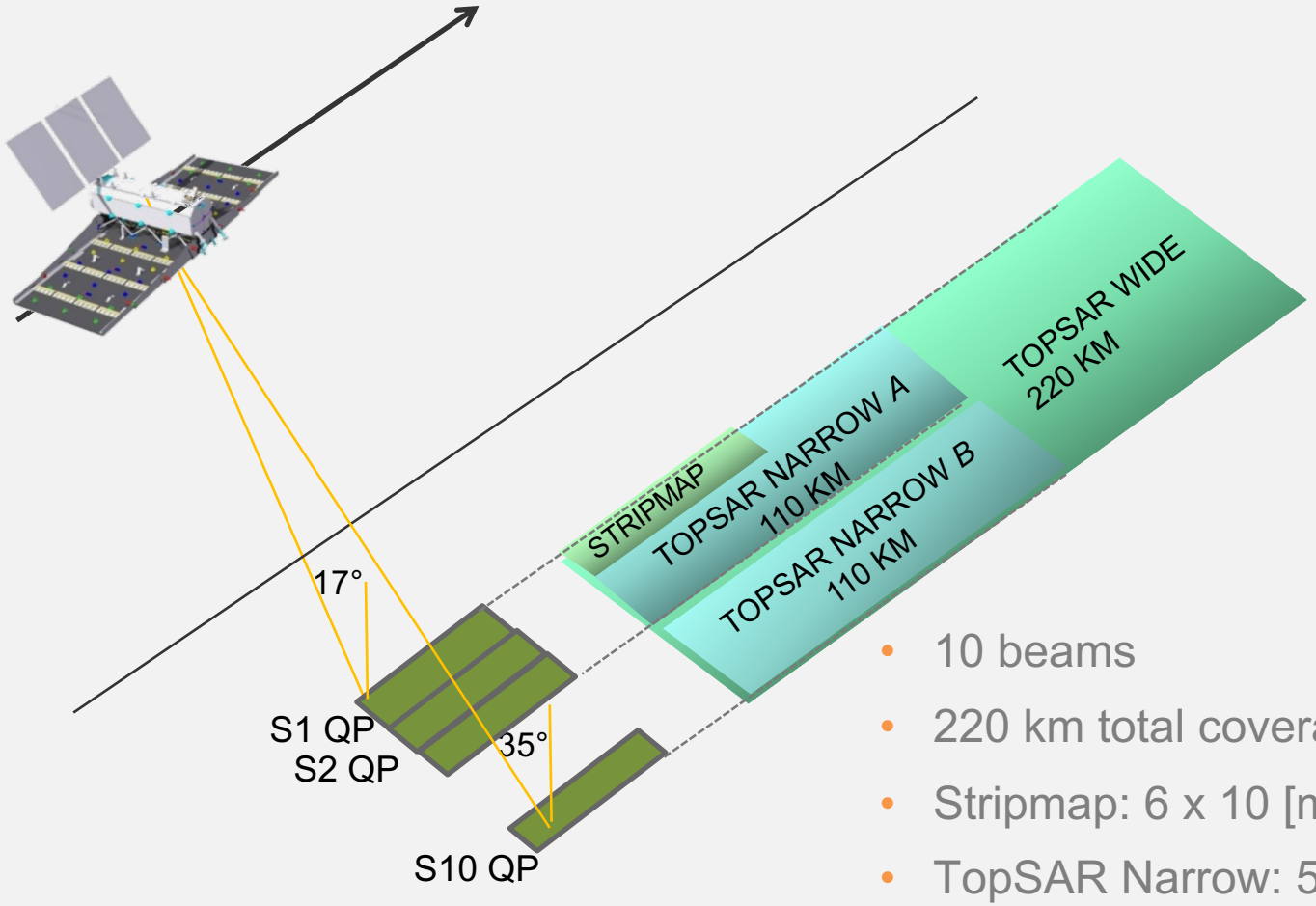
- SAOCOM mission overview
- SAOCOM Commissioning Phase
- Results from ARESYS independent CP
- Conclusion

SAOCOM mission overview

- **Satellites**: Constellation of 2 twin satellites
- **Orbit**: sun-synchronous, 625 – 650 km altitude
- **Payload**: L-band SAR instrument, 50 MHz band
- **Antenna**: full-pol, active array antenna (7 x 20 phase centres)



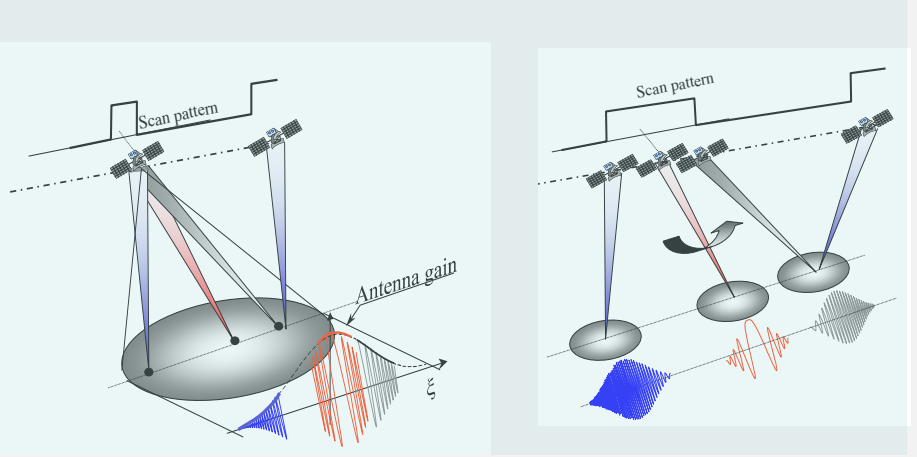
SAOCOM Quad POL mode



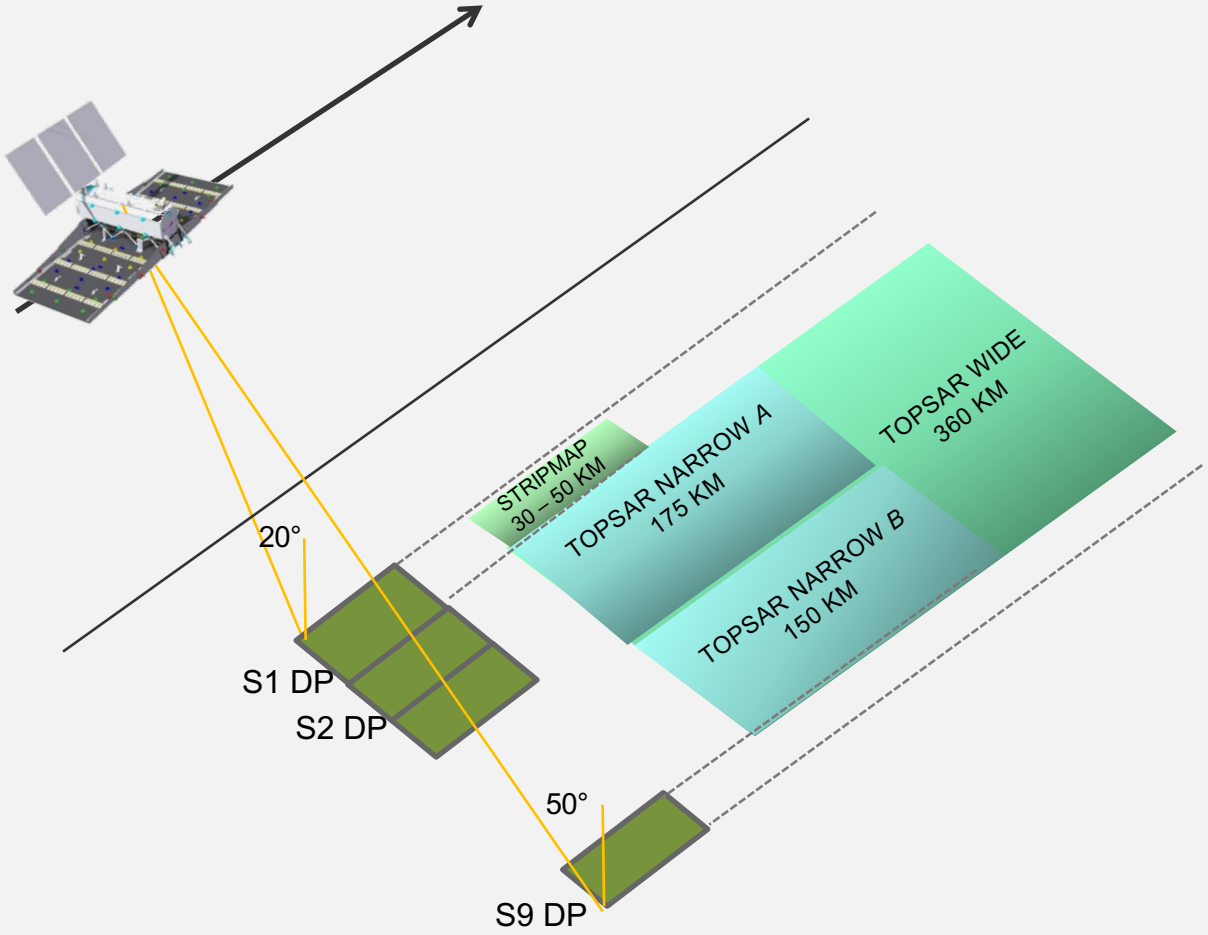
- 10 beams
- 220 km total coverage
- Stripmap: 6 x 10 [m]
- TopSAR Narrow: 50 x 10 [m]
- TopSAR Wide: 100 x 10 [m]

The TOPSAR mode is chosen to maximize coverage versus geometric & radiometric resolution:

- LOW scalloping
- Wide coverage
- High resolution
- Scanning timeline optimization possibility

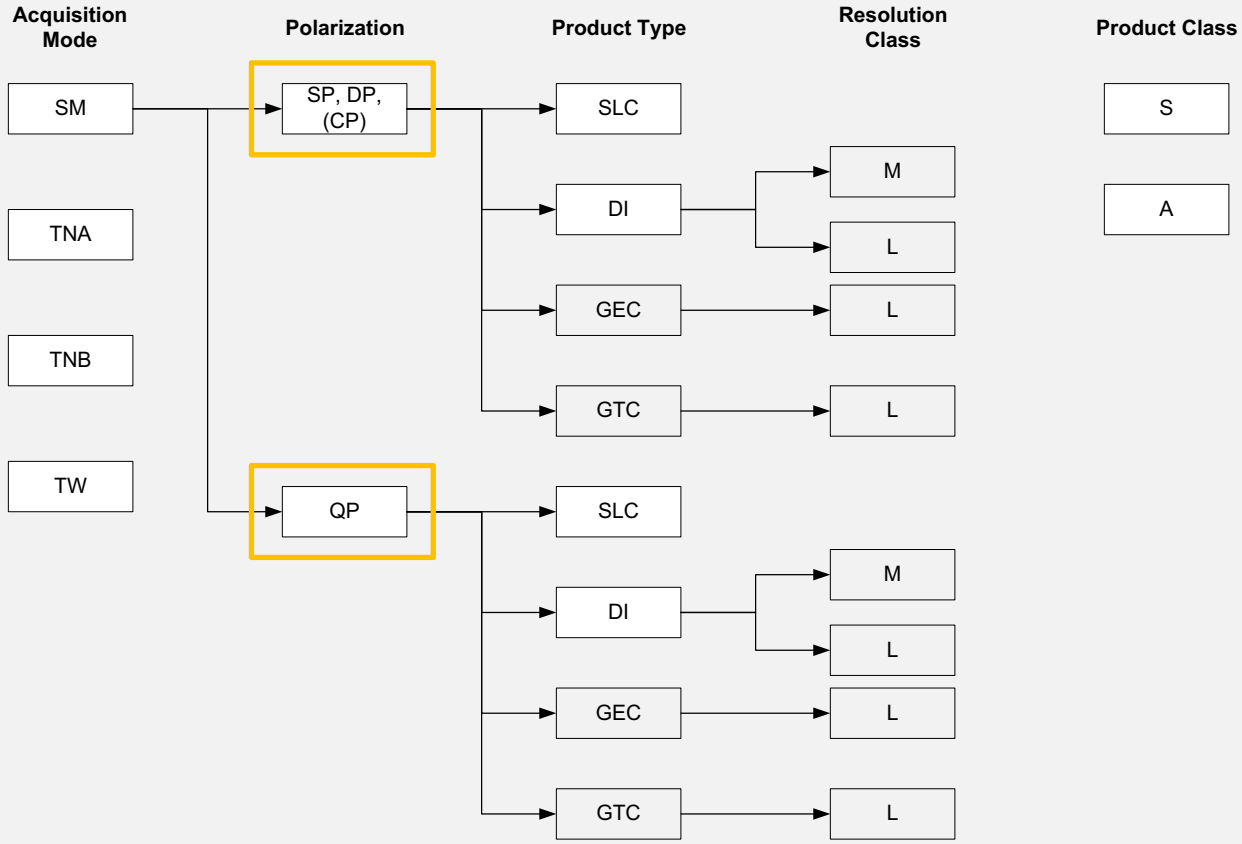


SAOCOM Dual POL mode



- 9 beams
- 430 km maximum coverage
- 360 km total coverage
- TopSAR mode is also exploited
- Stripmap: 5 x 10 [m]
- TopSAR Narrow: 30 x 10 [m]
- TopSAR Wide: 50 x 10 [m]

SAOCOM products tree



- **8 Modes**
- **5 products per mode**:
  - **Single Look Complex (SLC)**: Complex data in slant range, radiometrically calibrated with no geometric corrections.
  - **Detected Image (DI)**: Data projected to ground range, radiometrically calibrated and georeferenced (Medium and Low resolutions).
  - **Ground Ellipsoid Corrected (GEC)**: Radiometrically calibrated, geocoded and georeferenced.
  - **Ground Terrain Corrected (GTC)**: Radiometrically calibrated, geocoded using DEM and georeferenced.
- **40 Imaging Products**

SAOCOM Commissioning Phase

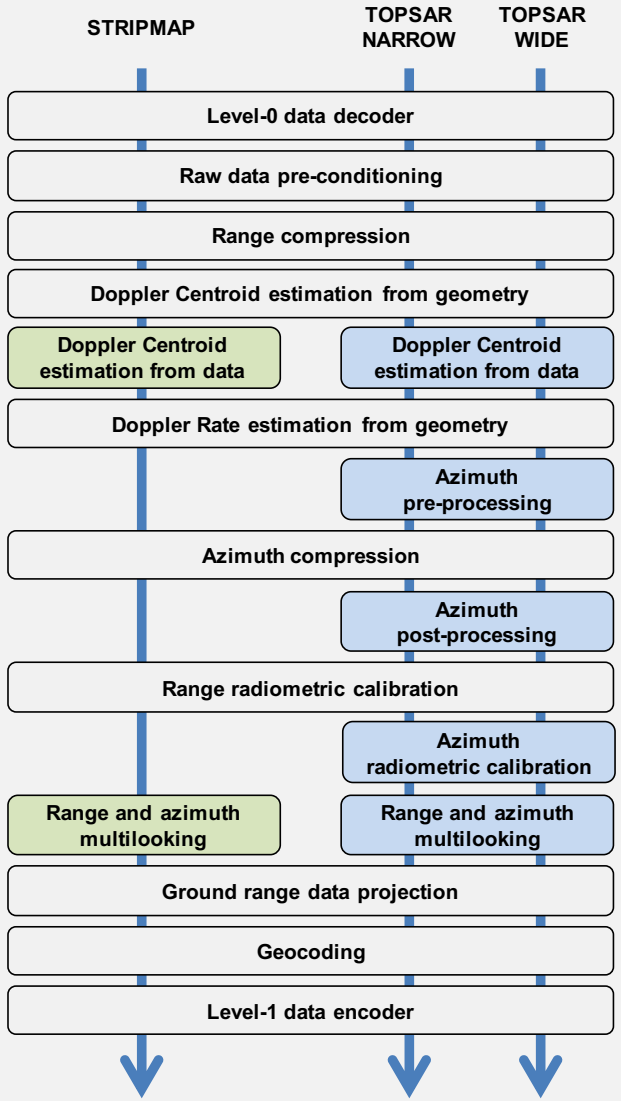
- SAOCOM-1A was successfully launched on 7th October 2018
- The first months of the mission have been dedicated to the functional verification of the instrument
- The first image was acquired on 25th October 2018
- The calibration and validation activities of the CP have started in December 2018
- SAO-1A CP completed on 30th September 2019, TopSAR verification activities under completion
- SAOCOM-1B launch foreseen for March 2020

Detail of the first SAOCOM-1A image:
StripMap (DS5), Dual Pol (DV)
Composed image (R: VH, G: 2VH + VV, B: VV)

SAOCOM: ARESYS involvement

ARESYS has been involved in SAOCOM program since the early phases of the mission:

- **System design**: ARESYS was responsible of the SAR modes design and of SAR performance calculation (including TopSAR modes)
- **Operational processor**: ARESYS developed the SAOCOM SAR Processor (SSP), the highly tailored operational SAR processing solution selected by CONAE for the SAOCOM L-Band SAR mission ground segment. SSP natively manages the all the SAOCOM acquisition modes including STRIPMAP, TOSAR Narrow and TOPSAR Wide modes.
- **System calibration**: ARESYS provides expert support and analysis tools for the Commissioning Phase activities



ARESYS independent SAOCOM CP

ARESYS has been appointed by CONAE to perform an independent processing and analysis of the data during commissioning phase, providing an independent assessment of:

- **Radiometric calibration:** absolute from point targets RCS analysis (CRs and transponder) and relative from distributed target areas such Rain Forest (Amazonia and Congo)
- **Pointing calibration:** elevation pointing calibration from Notch acquisitions and azimuth pointing calibration from data Doppler Centroid estimates
- **IRF analysis:** IRF parameters (resolution, side lobes, …) from acquisitions over CRs and transponder
- **Geometric calibration:** azimuth and range localization accuracy from acquisitions over CRs and transponder
- **Polarimetric calibration:** co-registration offsets, channel imbalance and & cross-talk estimation

Elevation Pointing calibration

- Dedicated Elevation Notch acquisitions have been performed to verify the SAOCOM roll pointing
- The data elevation profiles are fitted with a three parameters model to estimate the actual sensor elevation pointing

Overall calibration factor

Noise profile as a function of off-boresight angle (ϑ)

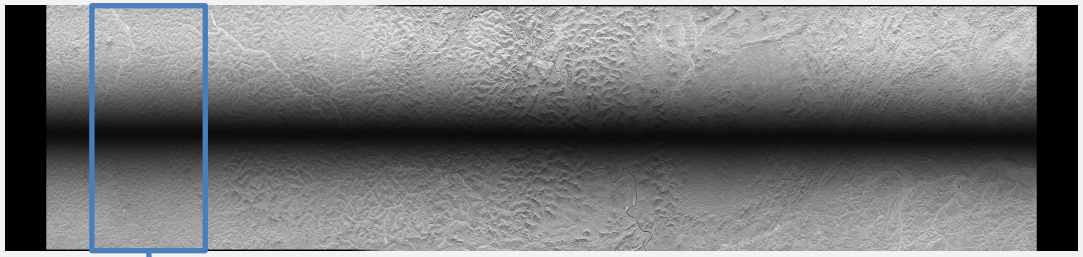
$$d(\vartheta) = k \cdot p(\vartheta - \boldsymbol{\vartheta_{MIS}}) + n \cdot f(\vartheta)$$

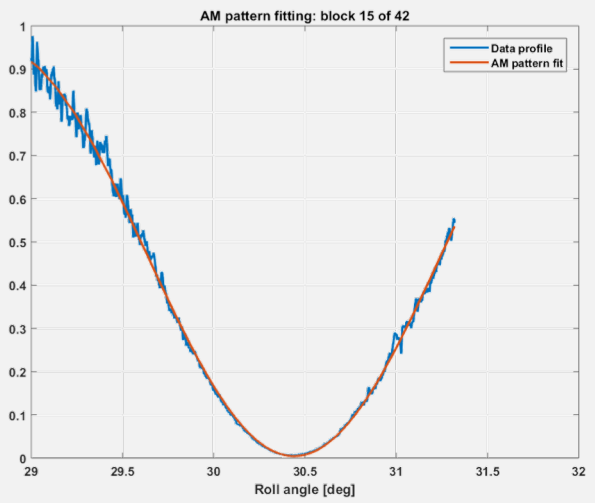
Data profile as a function of off-boresight angle (ϑ)

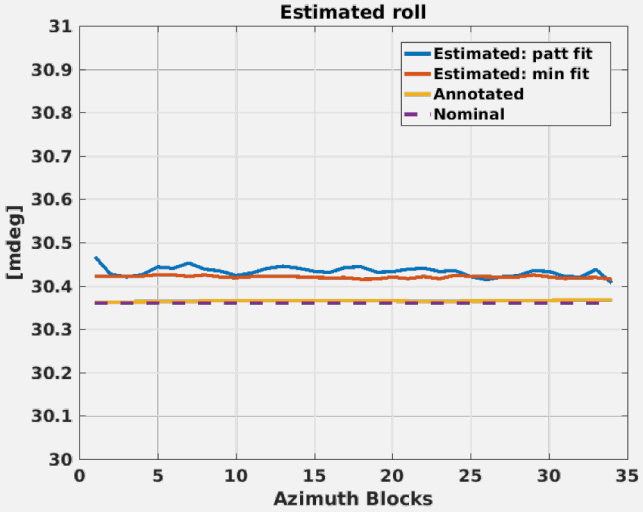
Elevation Notch pattern

Mis-pointing to be estimated

Noise calibration factor







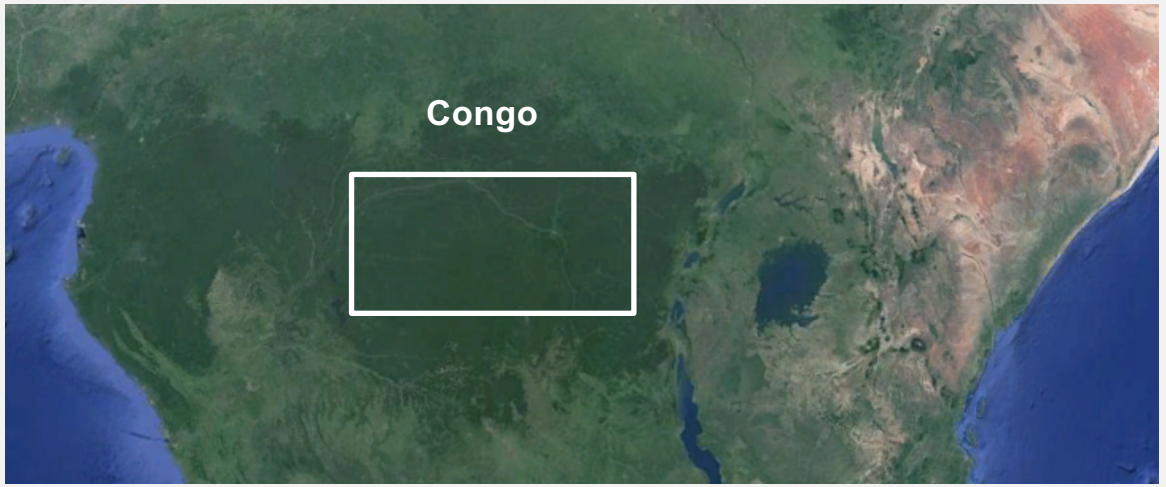
Elevation Pointing results

- 15 Elevation Notch products analyzed
- Consistent results from all the analyzed products
- Analysis of EN Rain Forest acquisitions (best accuracy) shows that the pointing is close to nominal with a small offset of +0.08 degrees
- The analysis of EN acquisitions all over the world (low accuracy due to data structures) shows no evident latitude dependent trends

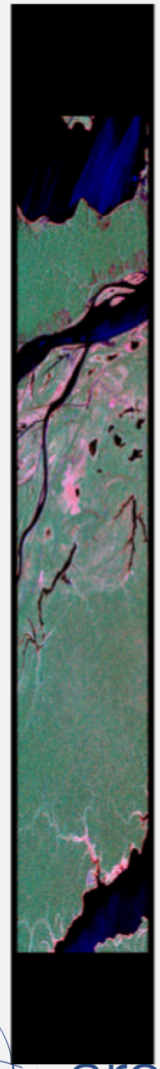
ID	Date	Pol.	Length [s]	Pass	Location	Topography [m]	Roll Bias [deg]
3265	**05/12/2018**	**DPH**	**46**	**A**	**Congo**	**520**	**0.12**
3221	**06/12/2018**	**DPV**	**80**	**D**	**Congo**	**510**	**0.08**
6490	19/01/2019	DPH	10	A	Canada	500	0.08
6492	19/01/2019	DPV	12	A	Canada	580	0.11
6494	19/01/2019	DPH	18	D	Argentina	60	0.05
6495	19/01/2019	DPV	19	D	Argentina	100	-0.04
6496	21/01/2019	DPH	18	D	Russia	240	0.16
6498	21/01/2019	DPV	12	D	Russia	265	0.14
6500	21/01/2019	DPH	17	A	Australia	110	0.05
6502	21/01/2019	DPV	8	A	Australia	205	-0.04
6504	21/01/2019	DPH	13	D	Australia	320	-020
6506	21/01/2019	DPV	11	D	Australia	1000	0.03
9809	**16/02/2019**	**DPH**	**70**	**A**	**Papua**	**120**	**0.09**
10783	**27/02/2019**	**DPV**	**86**	**A**	**Congo**	**400**	**0.07**
10784	**28/02/2019**	**DPH**	**116**	**D**	**Amazon**	**100**	**0.07**

Rain Forest calibration sites

- 2 different Rain Forest areas (Amazon and Congo) are exploited for the CP calibration activities
- Stripmap and TopSAR acquisitions over Rain Forest are exploited to verify Elevation Antenna Patterns and beam-to-beam (relative) radiometric offsets (patterns are the same unlike S-1)
- The γ-profiles derived from the homogeneous areas of the RF are assumed to be flat
- TopSAR data are used to verify de-scalloping performance as well



Rain Forest data processing



SLC product

Noise removal

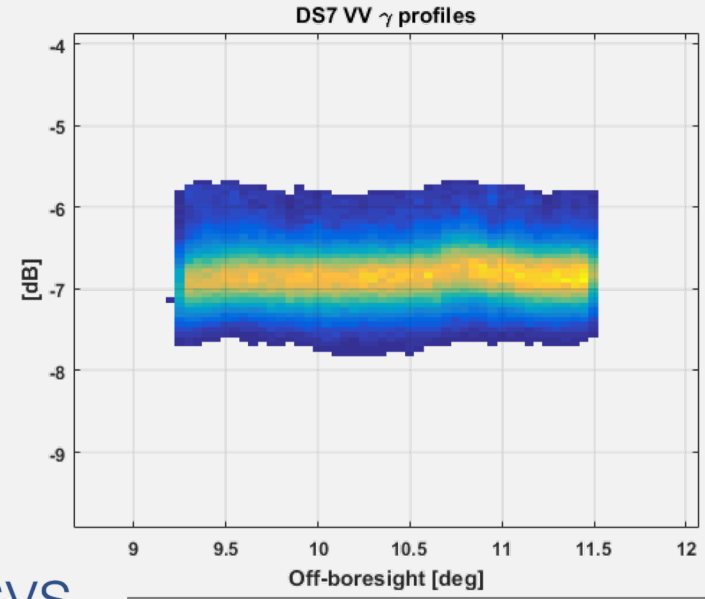
Data masking

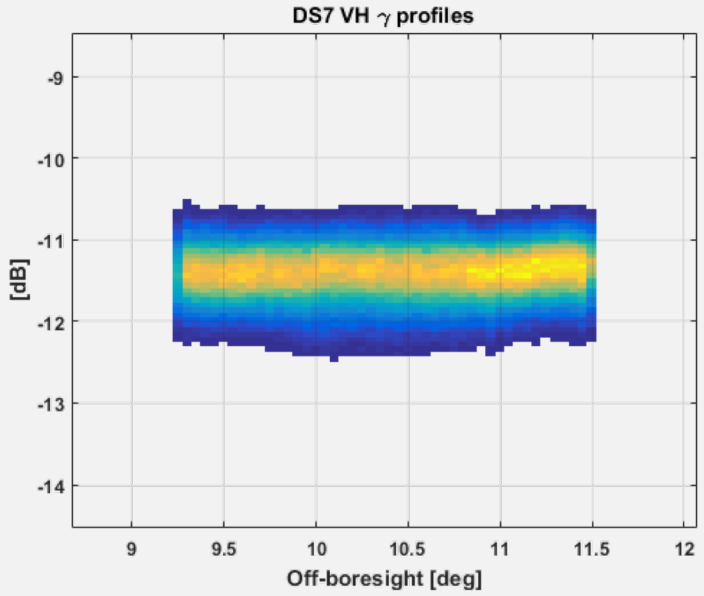
Geometric calibration (σ^0->γ^0)

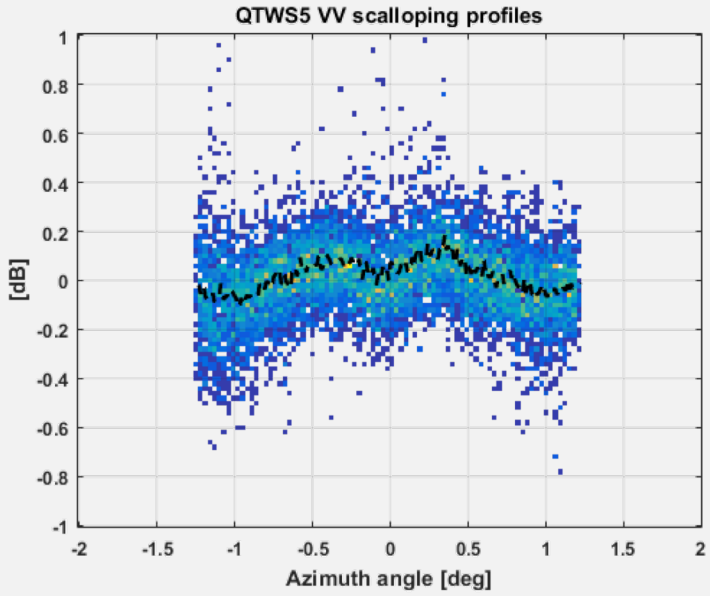
γ-profiles filtering

γ-profiles

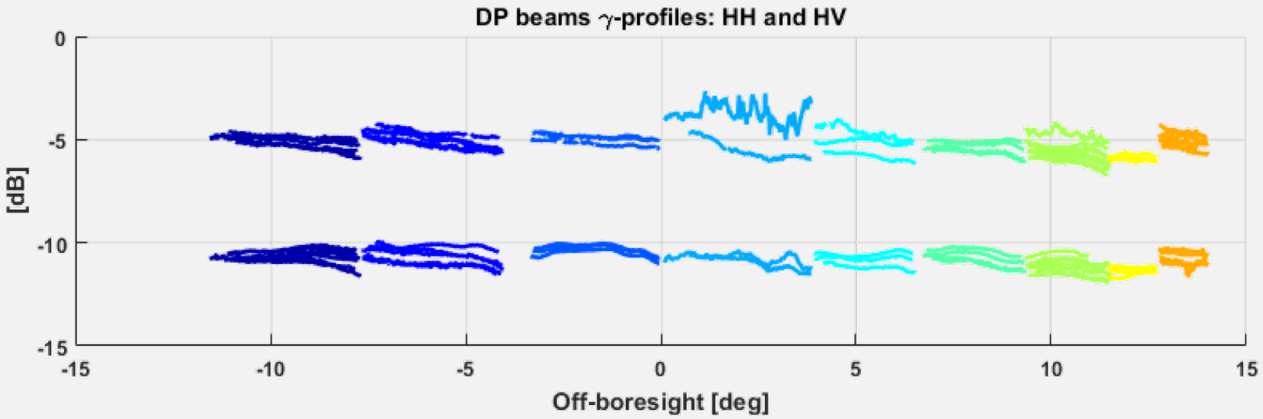
Scalloping profiles (TopSAR)

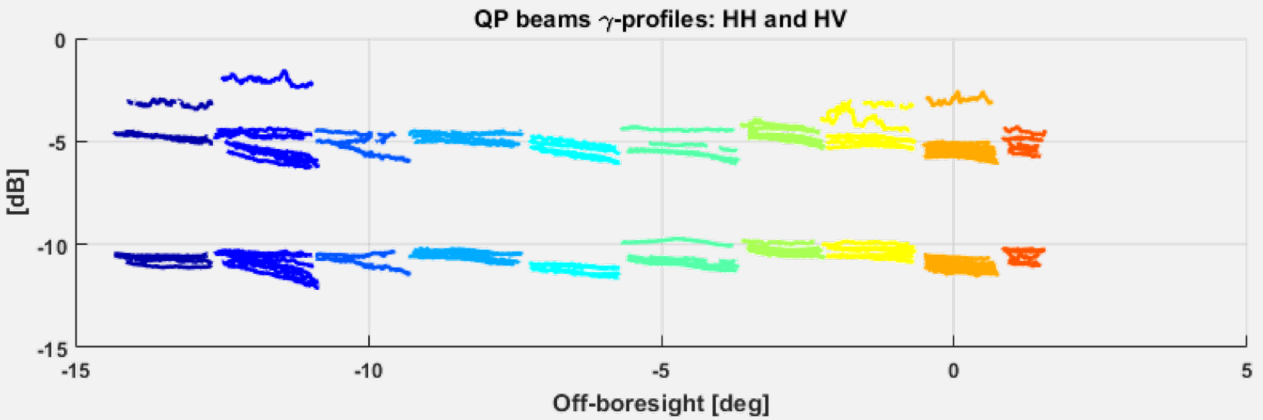


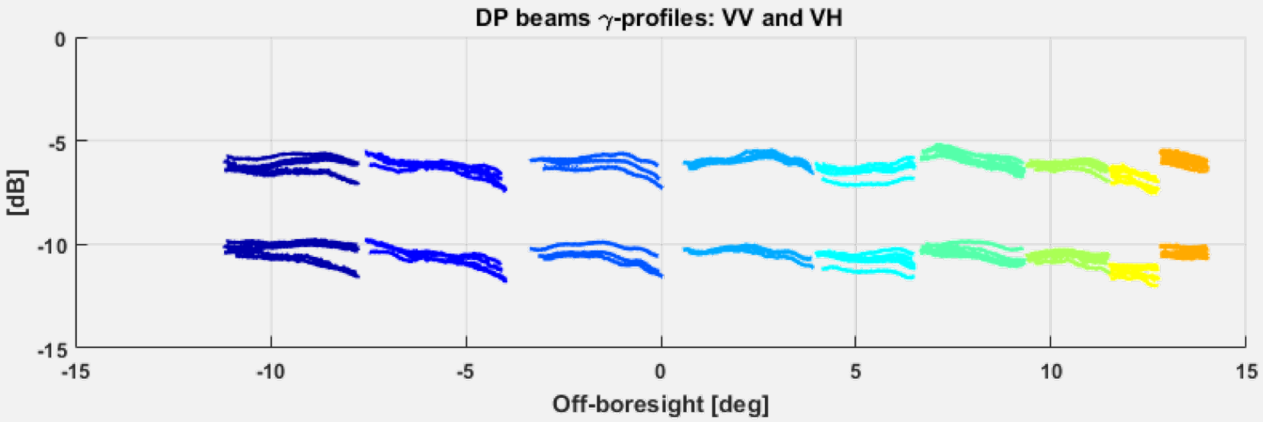


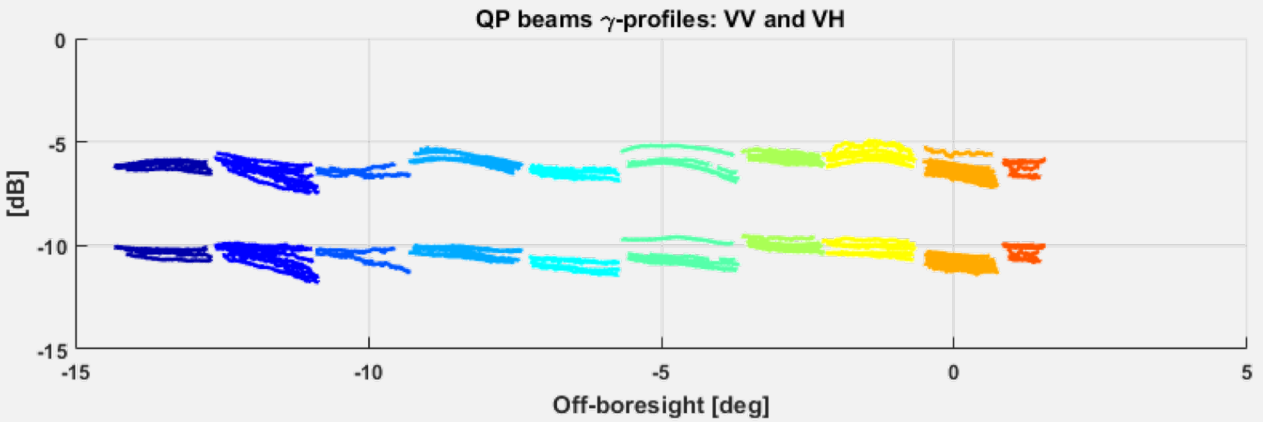


Rain Forest γ-profiles

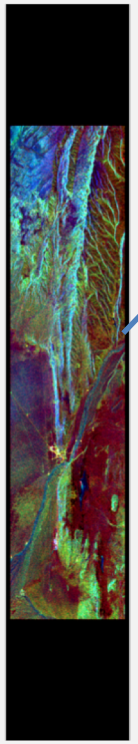


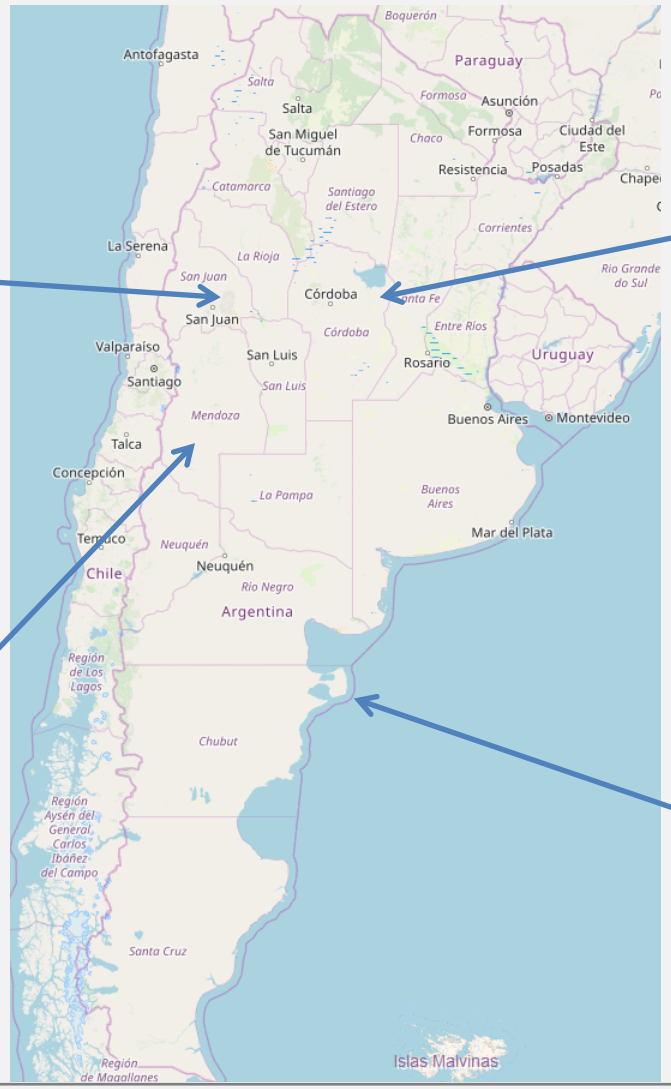


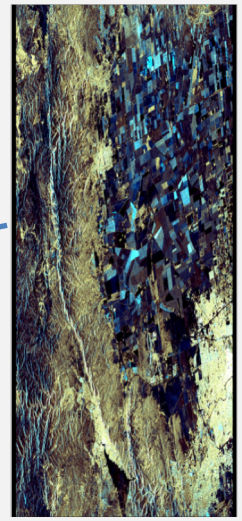




Point target calibration sites

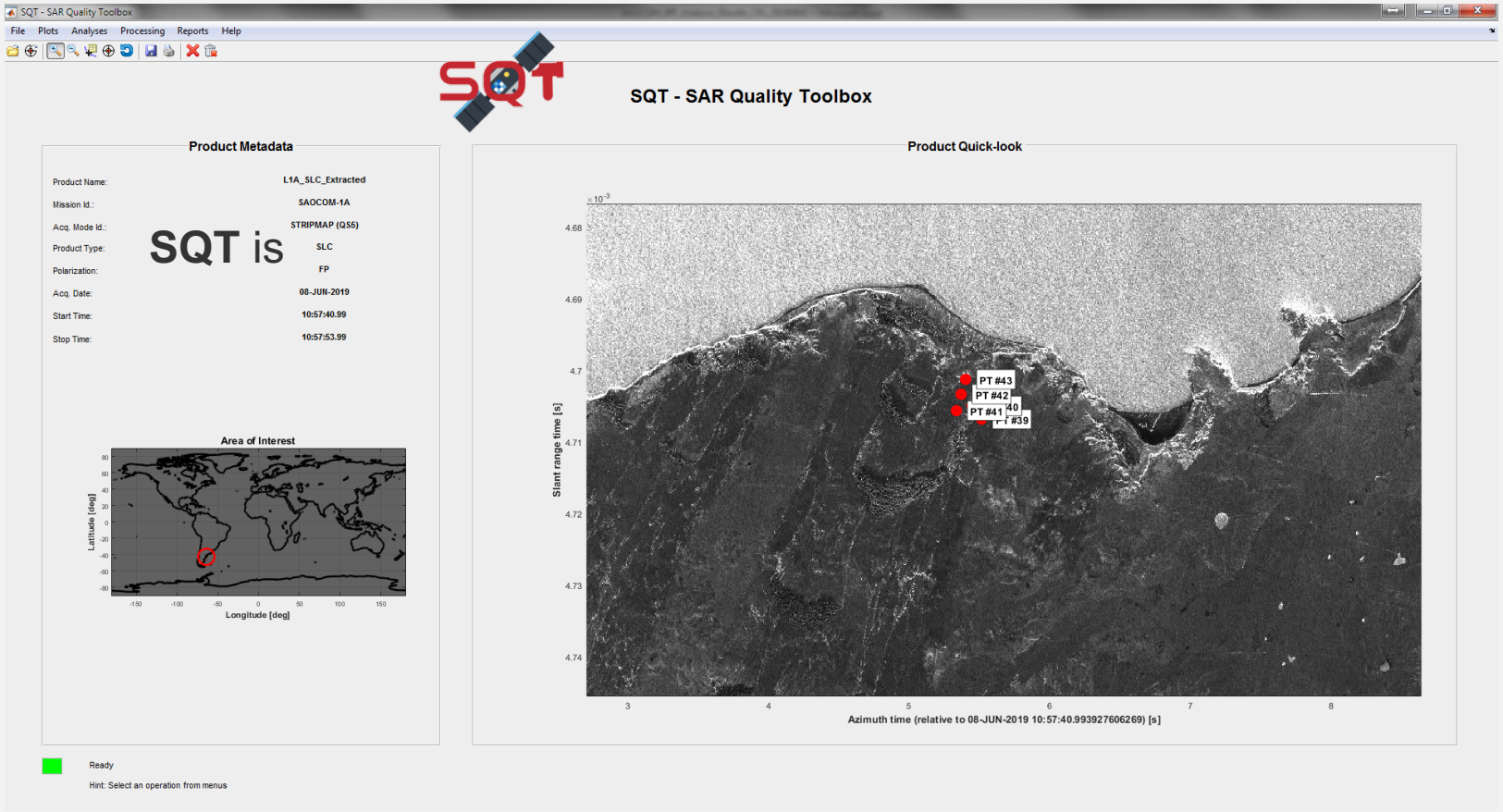


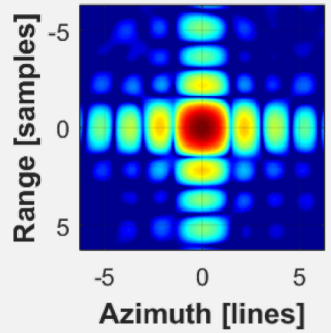




- Acquisitions over 4 dedicated calibration sites are planned to get absolute calibration and verify IRF properties
- 30 Corner Reflectors (3 m leg) and 1 Polarimetric Active Radar Calibrator
- Acquisition plan and pointing of the CRs optimised to ensure maximum coverage of the swaths to be calibrated

IRF analysis





IRF Analysis

Resolution

Range resolution : 6.7292 [m]

Azimuth resolution : 4.9877 [m]

PSLR

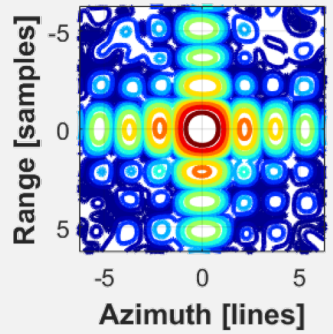
Range PSLR : -13.4602 [dB]

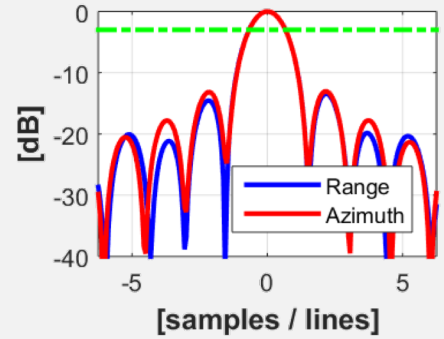
Azimuth PSLR : -13.0436 [dB]

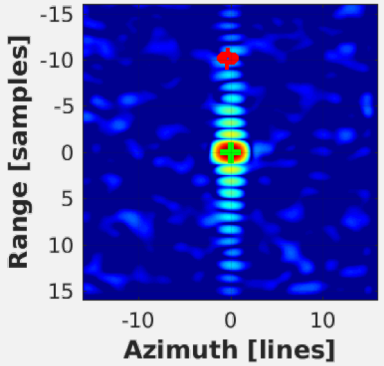
ISLR

Range ISLR : -11.0173 [dB]

Azimuth ISLR : -10.0833 [dB]







IRF Analysis

Localization Error

Range LE : 38.0321 [m]

Azimuth LE : 1.2193 [m]

All analyses performed with Aresys SAR Quality Toolbox, a collection of advanced and interactive tools for the assessment of the scientific quality of SAR data

Resolution verification

	H/H		V/V	
Beam	Rg. Res. [m]	Az. Res. [m]	Rg. Res. [m]	Az. Res. [m]
DS1				
DS2				
DS3				
DS4	9.40	5.16		
DS5	10.13	5.53	9.71	5.18
DS6	10.01	5.08	9.88	4.98
DS7	9.95	5.73	9.52	5.86
DS8	10.38	5.33	9.58	5.43
DS9			9.20	5.00

Theoretical: 10 x 5 m

	H/H		V/V	
Beam	Rg. Res. [m]	Az. Res. [m]	Rg. Res. [m]	Az. Res. [m]
QS1	10.12	6.12	10.37	6.06
QS2				
QS3				
QS4				
QS5	9.87	6.20	9.86	6.20
QS6	9.81	6.08	9.64	6-10
QS7	10.34	6.44	10.28	6.19
QS8	10.65	6.17	9.68	6.16
QS9				
QS10	10.13	6.07	10.15	6.01

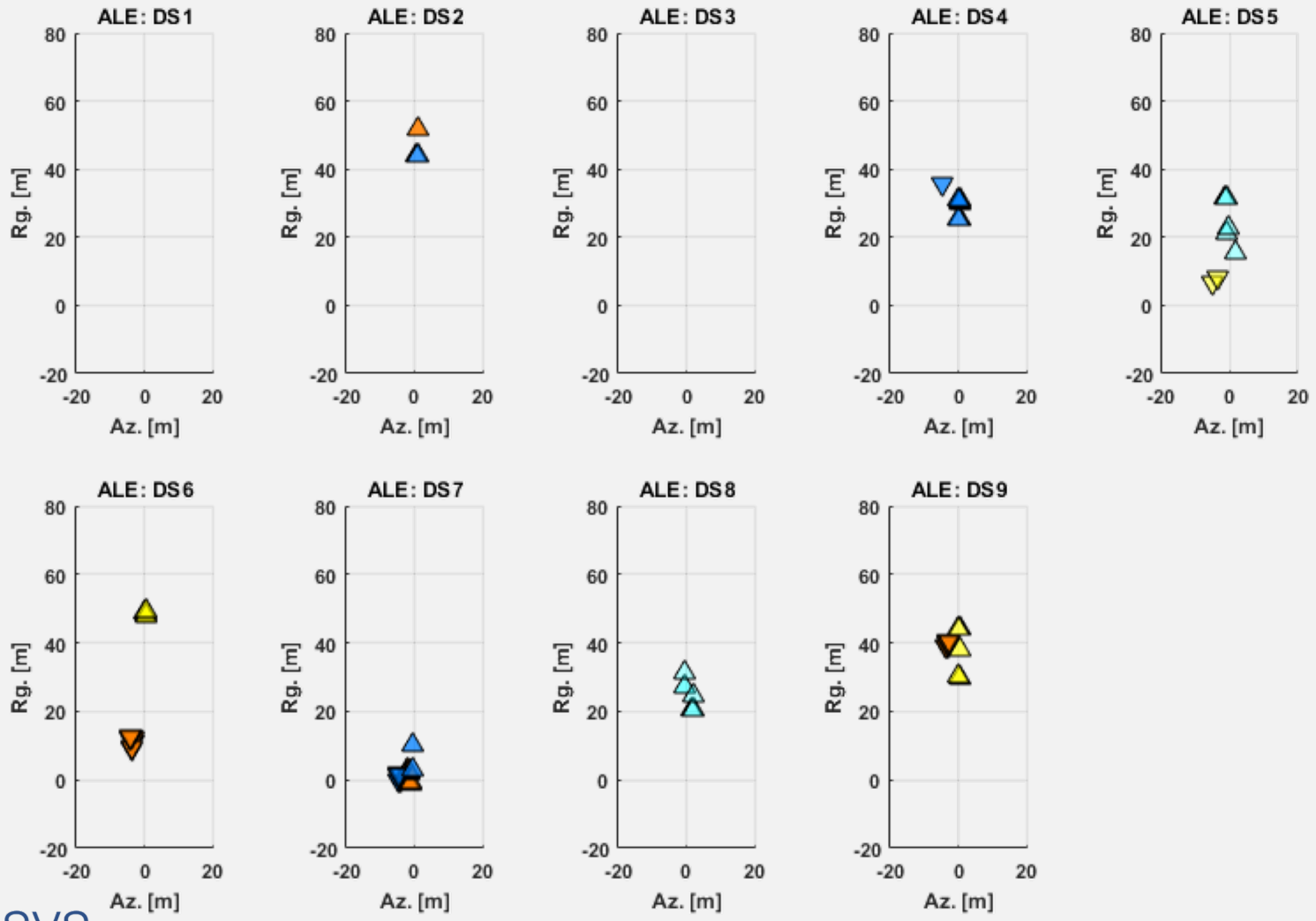
Theoretical: 10 x 6 m

Geolocation accuracy: DS beams

CAS
CET
MAN
PIR
SOS

△ Ascending

▽ Descending



- 2 days precise orbits
- No ionospheric/tropospheric correction
- No beam dependent instrument bias correction

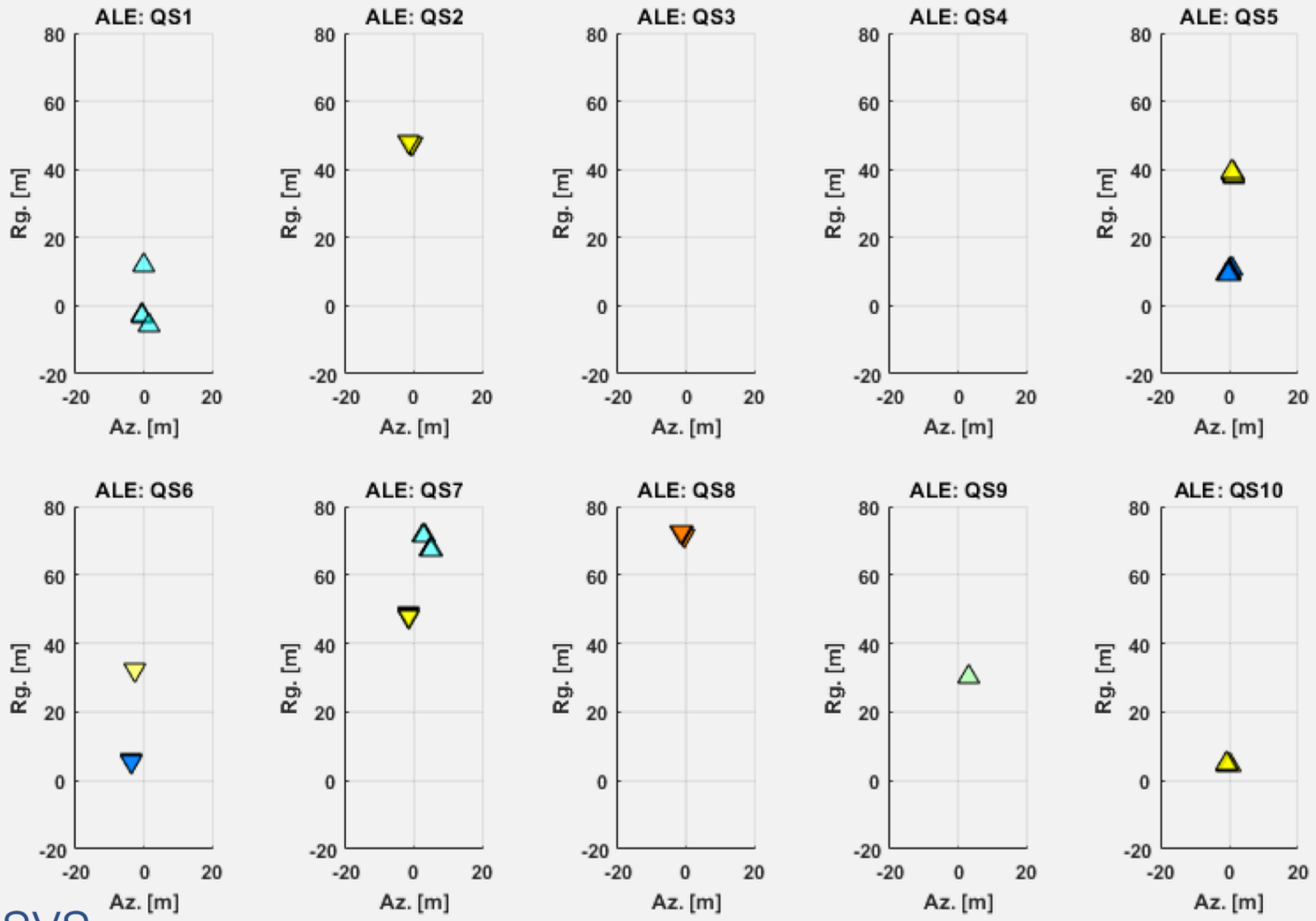
Beam	Rg. ALE [m]	Az. ALE [m]
DS1		
DS2	48,60 ± 3,91	0,90 ± 0,15
DS3		
DS4	30,56 ± 3,58	-0,78 ± 2,15
DS5	16,90 ± 10,21	-2,03 ± 2,33
DS6	21,48 ± 16,81	-2,51 ± 1.,78
DS7	1,88 ± 2,89	-2,13 ± 1,29
DS8	25,14 ± 4,11	0,83 ± 1,25
DS9	37,91 ± 4,48	-1,66 ± 1,68

Geolocation accuracy: QS beams

CAS
CET
MAN
PIR
SOS

△ Ascending

▽ Descending



- 2 days precise orbits
- No ionospheric/tropospheric correction
- No beam dependent instrument bias correction

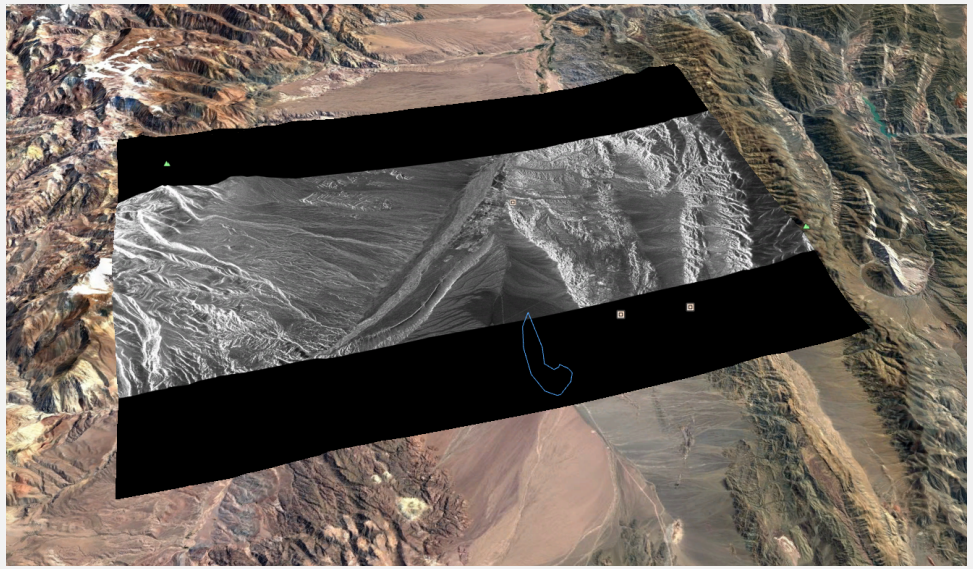
Beam	Rg. ALE [m]	Az. ALE [m]
QS1	1,17 ± 8,41	0,48 ± 1,04
QS2	47,95 ± 0,20	-1,06 ± 0,34
QS3		
QS4		
QS5	22,25 ± 14,44	0,42 ± 0,58
QS6	11,01 ± 11,19	-3,46 ± 0,52
QS7	55,38 ± 10,50	0,27 ± 2,71
QS8	71,96 ± 0,61	-0,97 ± 0,45
QS9	30,37 ± 0,04	-3,26 ± 0,01
QS10	4,63 ± 0,15	-0,27 ± 0,47

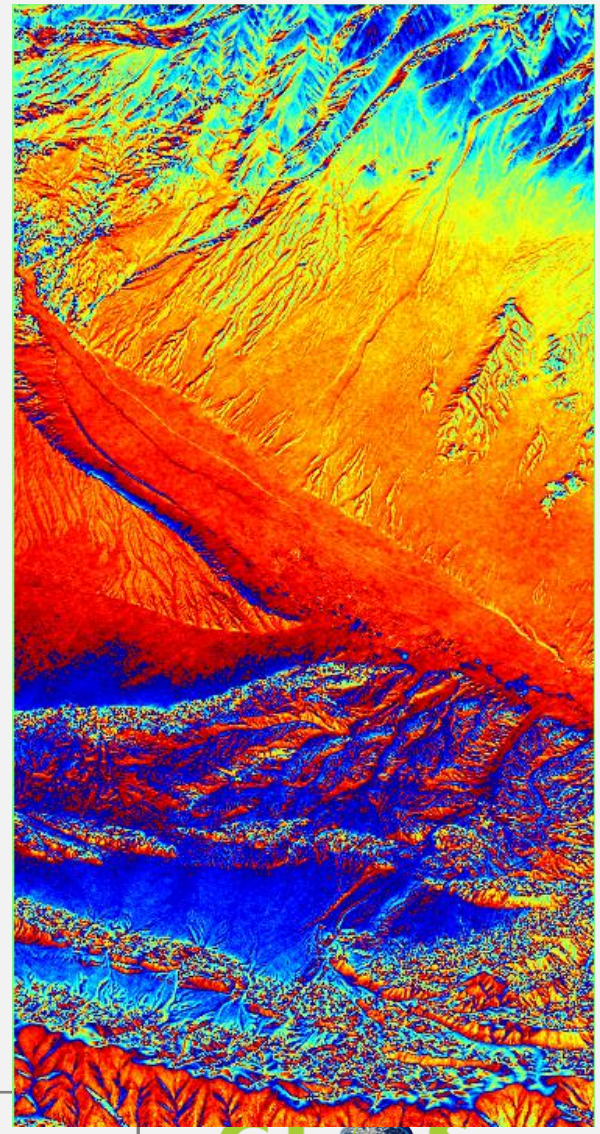
Bonus track: SAOCOM interferometry

- SAOCOM mission is not purposefully interferometric
- TopSAR burst synchronization is not a mission requirement but could be possible in a few cases
- Stripmap interferometry is possible if normal baseline not exceeding critical baseline value

Interferogram over El Leoncito (CAS) calibration site in the Andes:

- Acq. 11847-S4DP-V (10th March 2019)
- Acq. 12499-S4DP-V (26th March 2019)





Obtained with ARESYS Generic Interferometric Processor

Summary and outlook

- Results of the Cal/Val activities independently performed by Aresys have been presented
- Cal/Val activities have been performed on a set of about 400 SAOCOM products
- Cal/Val activities for Stripmap are now complete. The presented results show that all the main quality parameters are within requirements
- Cal/Val activities for TopSAR are still on going
- Looking forward for SAOCOM-1B Commissioning Phase