DLR

esa

living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

FIRST RESULTS FOR THE SENTINEL-6 PERFORMANCE USING TRANSPONDER CAL/VAL INFRASTRUCTURE IN WEST CRETE

Fioretti Laura (1), Andrea Recchia (1), Craig James Donlon (2), Marco Fornari (3), Robert Cullen (2), Luisella Giulicchi (2), Pierre Féménias (4), Albert Garcia-Mondéjar (5), Adrian Flores(5), Ferran Gibert (5), Sergi Hernández(5), Stelios Mertikas(6), Konstantinos (Costas) Kokolakis (6); Claire Maraldi(7), Francois Boy(7), Samira Amraoui (8), Walter H. F. Smith (9), Alejandro Egido (9), Jean-Damien Desjonqueres(10), Demitris Piretzidis (11)

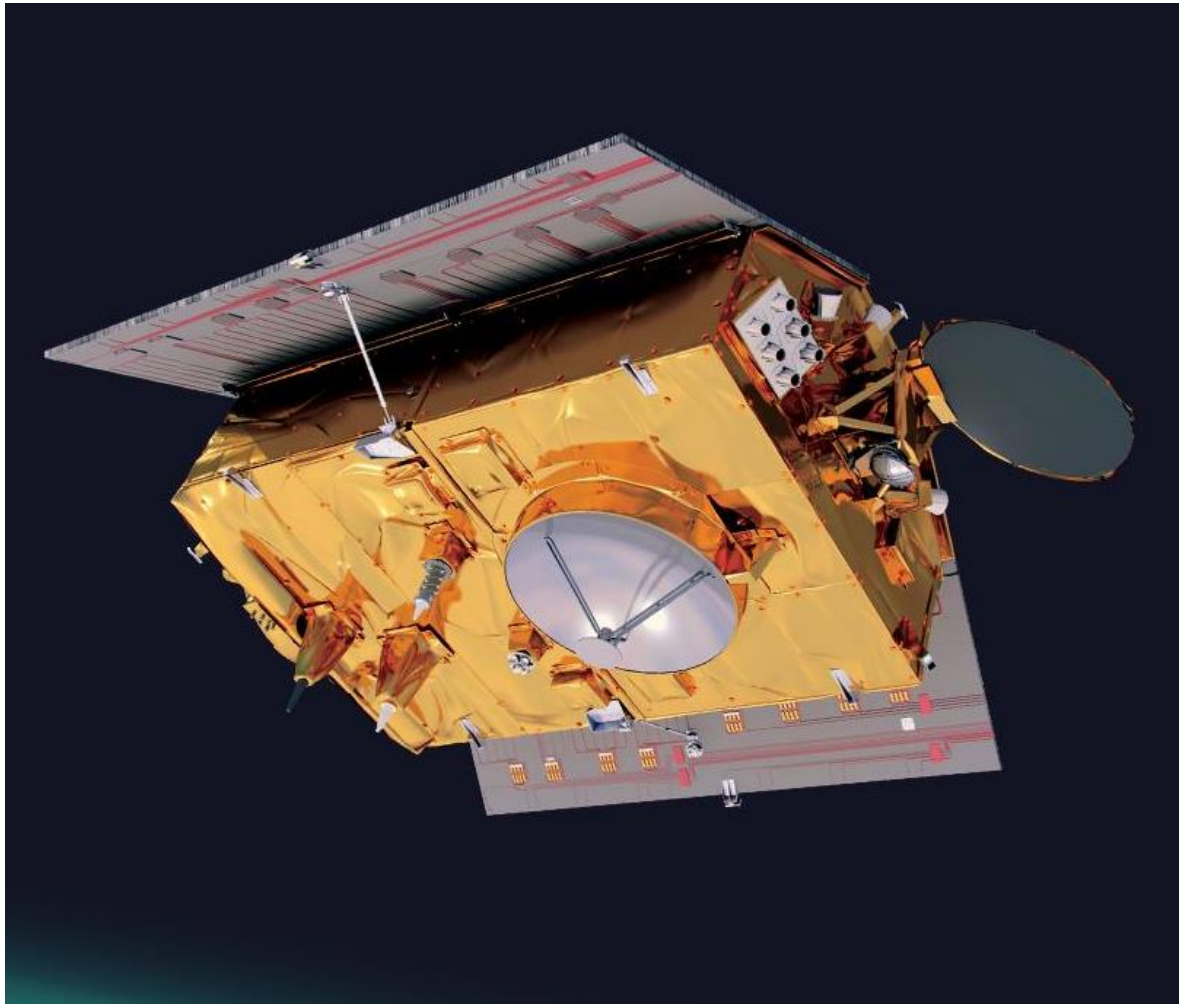
(1) Aresys, Italy; (2) ESA-ESTEC, Netherlands; (3) RHEA for ESA, Netherlands; (4) ESA-ESRIN, Italy; (5) IsardSAT, Spain; (6) Technical University of Crete, Greece; (7) CNES, France; (8) CLS, France; (9) NOAA, USA; (10) NASA/JPL, USA; (11) Space Geomatica PC, Greece

ESA UNCLASSIFIED – For ESA Official Use Only

25.05.2022

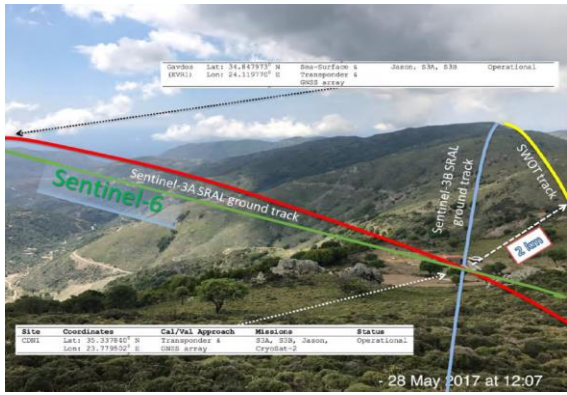
Outline

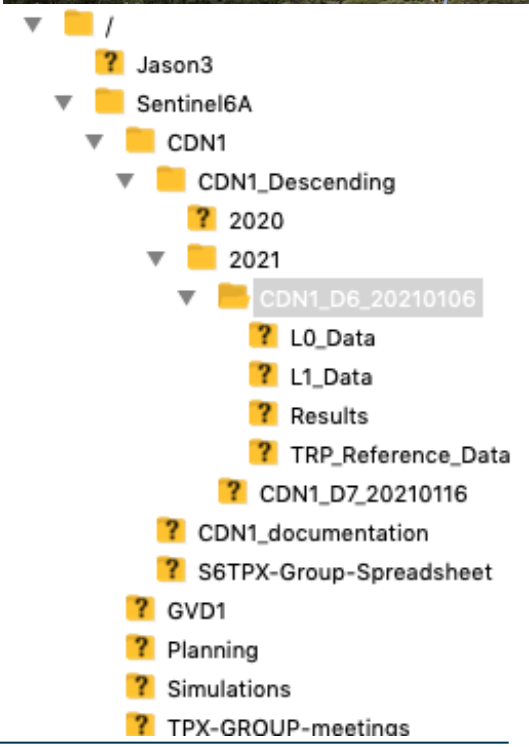
- Overview
  - S6TPX group
  - Cal/Val infrastructures
  - Performed processing and analysis
- Results
  - Range and datation bias comparative results
  - Corner reflector results (by isardSAT)
  - Jason-3 results (by TUC)
  - Resolution results (by Aresys)
- Conclusion



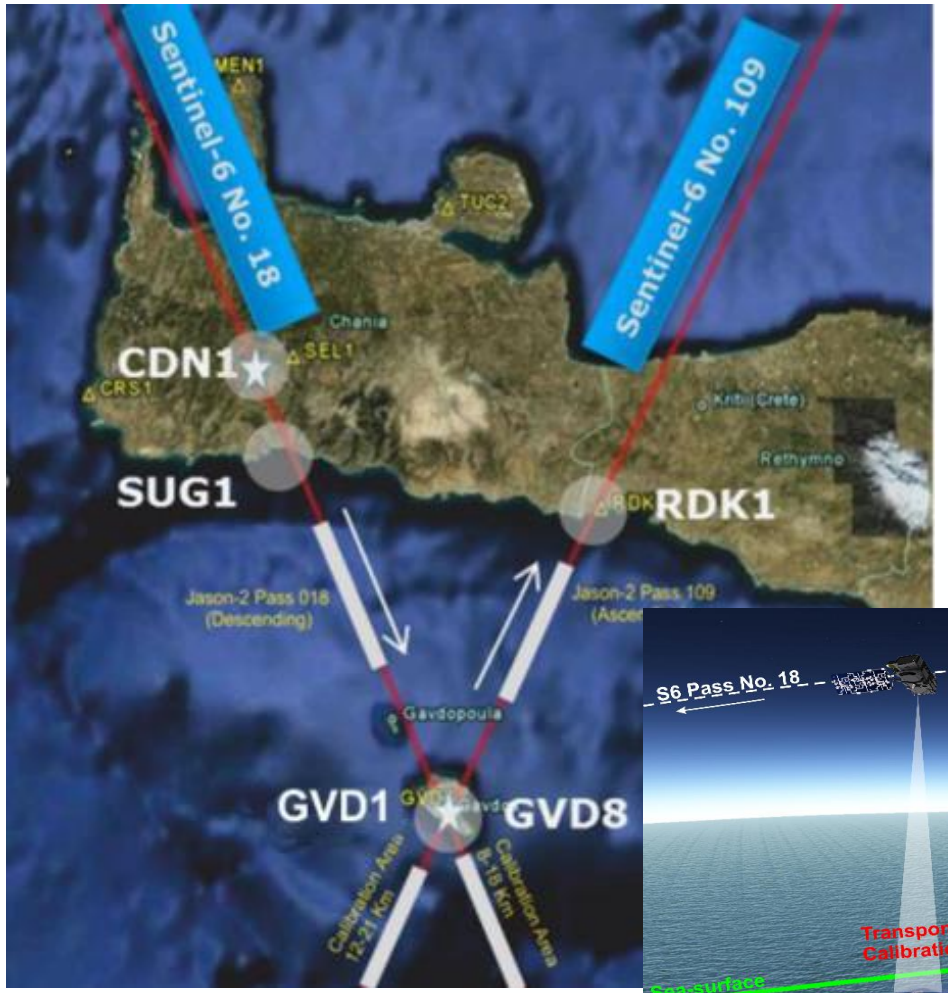
S6TPX Group Overview

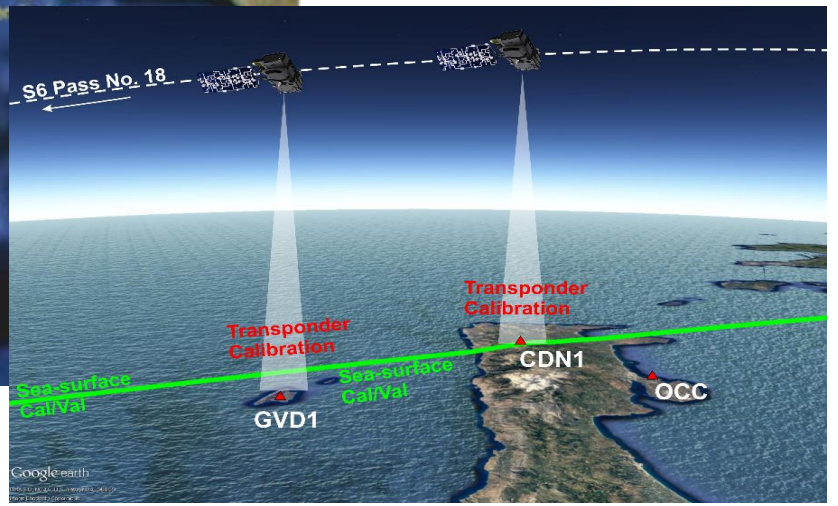
- S6TPX group was convened by ESA to work openly and collaboratively with transponder specialists (as part of the ESA FRM4S6 project – the ESA contribution to S6 Cal/Val),
- S6TPX group coordinates results with same input data (PDAP & GPP) collected:
  - By different teams,
  - Different independent processing systems,
  - Different statistical analyses,
  - Cal/Val infrastructures (Transponders: CDN1, GVD1, JPL; Corner reflectors).
- Met 22 times, before the Sentinel-6 November 2020,
- Full and open exchange of data, results, processing, corrections etc.,
- Aim of S6TPX group to confirm & monitor Sentinel-6 in flight performance,
- Results on Datation, Range bias and PTR characteristics.





Cal/Val Infrastructures Overview

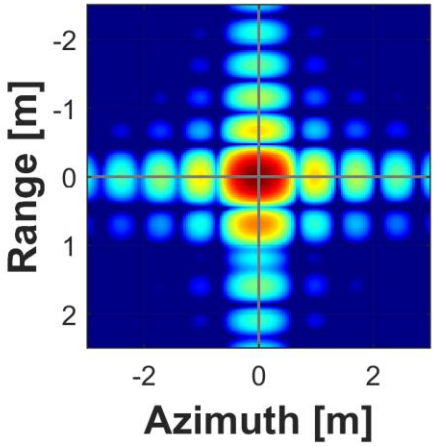




- Two transponders in Crete: CDN1 (Crete) and GVD1 (Gavdos),
- CDN1 and GVD1 separated 9 sec apart on D.18 Orbit,
- GVD1 located on ascending and descending orbits,
- Almost 50 passes on CDN1 and 20 passes on GVD1,
- Also evaluated:
  - isardSAT CR,
  - JPL TRP.

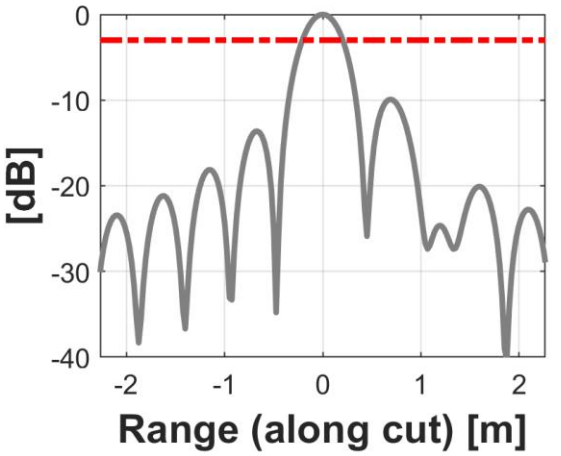
Data Analysis Overview

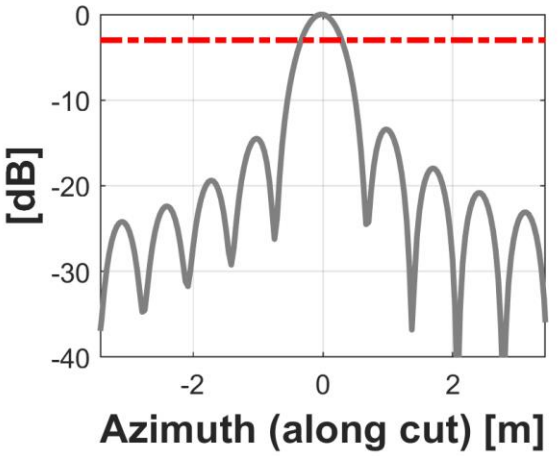
- Sentinel-6 L1A data are processed:
  - Delay-Doppler (low resolution),
  - Fully Focused (high resolution).
- Range biases are correted for
  - Transponder internal delay,
  - Atmospheric delay (wet + dry + iono),
  - Solid earth tides.
- IRF analyzed to assess:
  - Resolution,
  - Side Lobe Levels,
  - Range bias,
  - Datation bias.



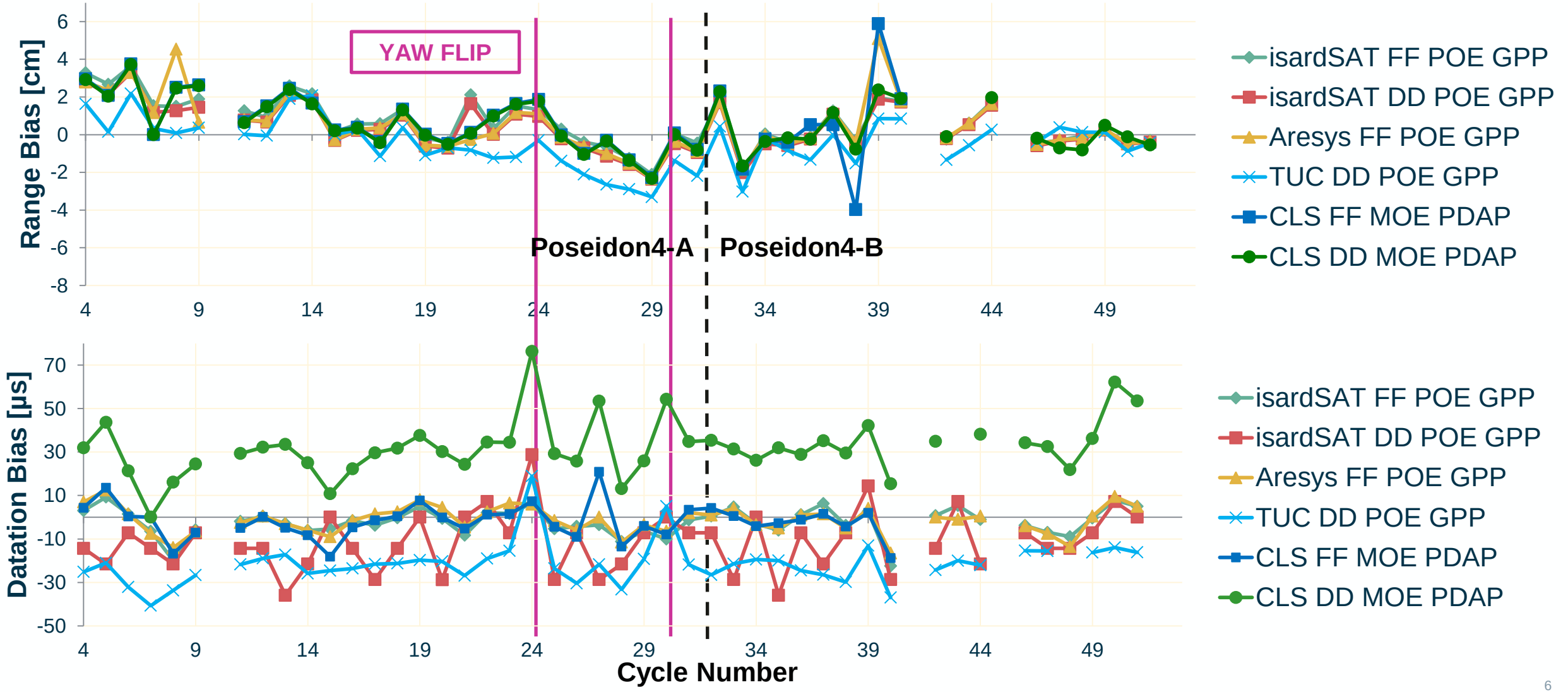
IRF Analysis

Resolution
Range resolution : 0.41 [m]
Azimuth resolution : 0.62 [m]
PSLR
Range PSLR : -9.91 [dB]
Azimuth PSLR : -13.39 [dB]
ISLR
Range ISLR : -8.64 [dB]
Azimuth ISLR : -10.81 [dB]

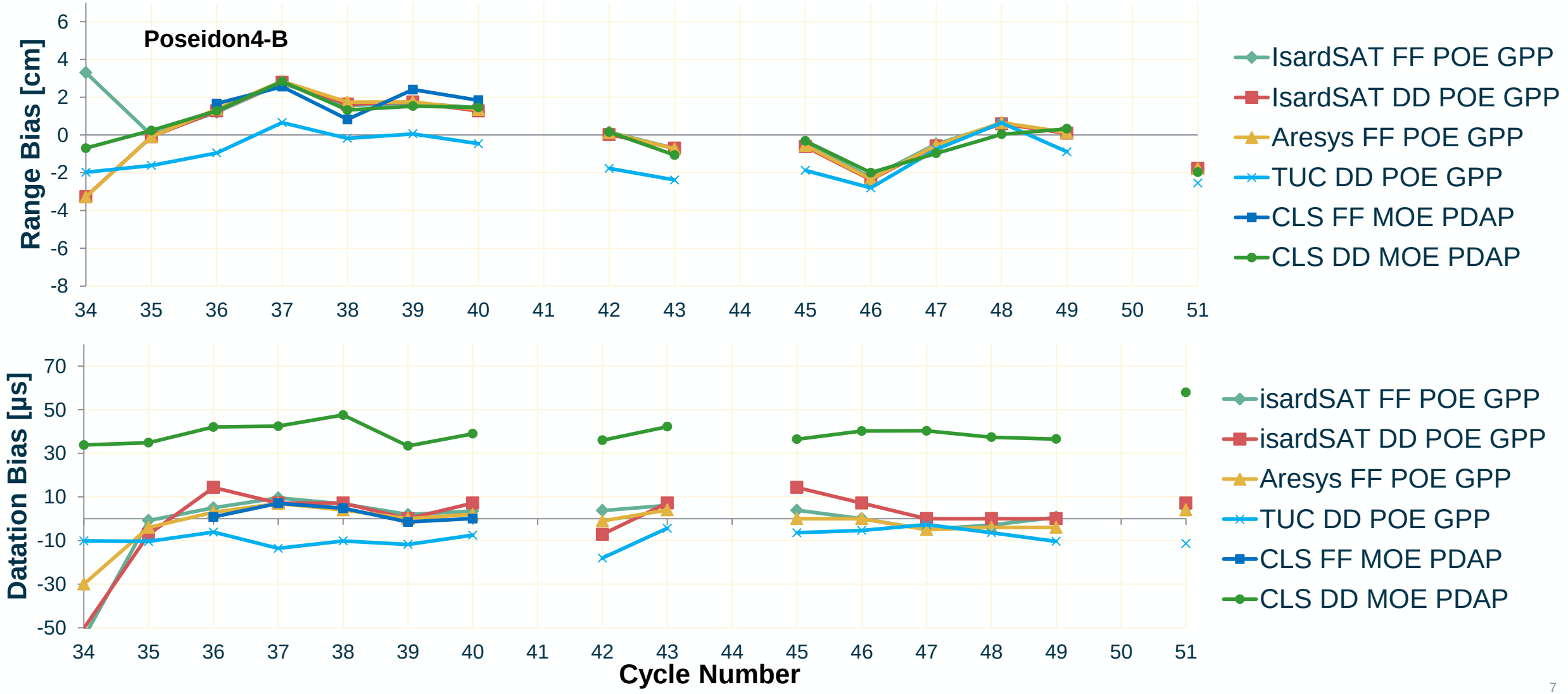




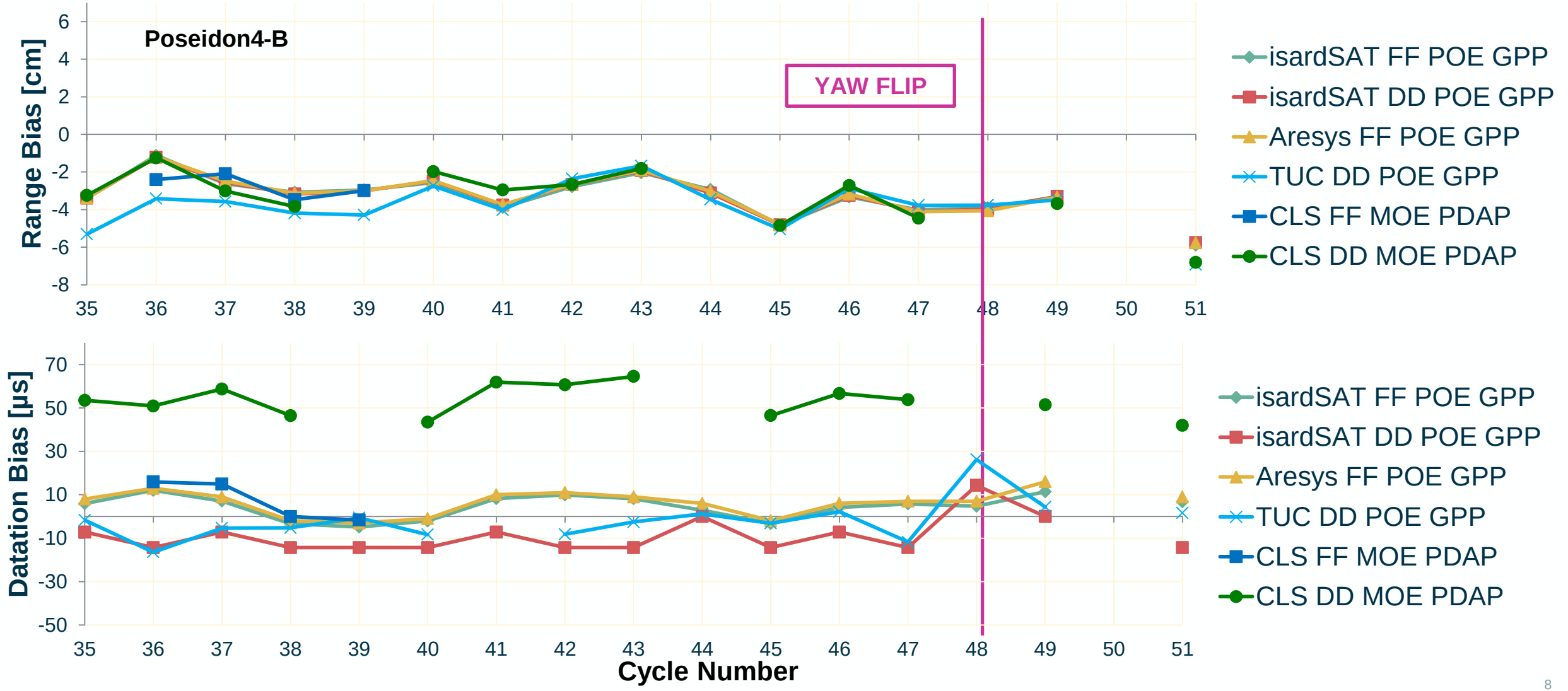
CDN1 - Descending Passes No.18



GVD1 - Descending Passes No.18



GVD1 - Ascending Passes No.109



Range & Datation Bias Summary

	CDN1 Desc				GVD1 Desc				GVD1 Asc			
	Rg Bias [cm]		Dat Bias [µs]		Rg Bias [cm]		Dat Bias [µs]		Rg Bias [cm]		Dat Bias [µs]	
	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std
CLS DD MOE PDAP	0.55	1.37	32.92	12.38	0.14	1.32	40.02	6.07	-3.33	1.40	53.14	6.92
TUC DD POE GPP	-0.46	1.26	-21.45	9.55	-1.12	1.08	-9.01	3.84	-3.81	1.20	-1.85	9.26
isardSAT DD POE GPP	0.36	1.23	-11.49	13.32	0.00	1.59	0.48	14.94	-3.28	1.05	-8.98	7.82
isardSAT FF POE GPP	0.64	1.27	-2.19	6.35	0.48	1.49	-1.14	14.73	-3.29	1.07	4.60	5.20
Aresys FF POE GPP	0.52	1.49	-1.28	6.20	0.04	1.61	-1.60	8.35	-3.26	1.06	6.44	5.47
CLS FF MOE PDAP	0.72	1.82	-2.09	7.98	1.86	0.62	2.26	3.19	-2.74	0.53	7.28	8.17

	CDN1 Desc		GVD1 Desc		GVD1 Asc	
	Rg Bias [cm]	Dat Bias [µs]	Rg Bias [cm]	Dat Bias [µs]	Rg Bias [cm]	Dat Bias [µs]
isardSAT DD - TUC DD	0.82	9.96	1.12	9.49	0.53	-7.13
isardSAT FF - Aresys FF	0.12	-0.91	0.44	0.46	-0.03	-1.84

Range & Datation Bias Summary

	CDN1 Desc				GVD1 Desc				GVD1 Asc			
	Rg Bias [cm]		Dat Bias [µs]		Rg Bias [cm]		Dat Bias [µs]		Rg Bias [cm]		Dat Bias [µs]	
	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std
CLS DD MOE PDAP	**0.55**	1.37	32.92	12.38	**0.14**	1.32	40.02	6.07	**-3.33**	1.40	53.14	6.92
TUC DD POE GPP	**-0.46**	1.26	-21.45	9.55	**-1.12**	1.08	-9.01	3.84	**-3.81**	1.20	-1.85	9.26
isardSAT DD POE GPP	**0.36**	1.23	-11.49	13.32	**0.00**	1.59	0.48	14.94	**-3.28**	1.05	-8.98	7.82
isardSAT FF POE GPP	**0.64**	1.27	-2.19	6.35	**0.48**	1.49	-1.14	14.73	**-3.29**	1.07	4.60	5.20
Aresys FF POE GPP	**0.52**	1.49	-1.28	6.20	**0.04**	1.61	-1.60	8.35	**-3.26**	1.06	6.44	5.47
CLS FF MOE PDAP	**0.72**	1.82	-2.09	7.98	**1.86**	0.62	2.26	3.19	**-2.74**	0.53	7.28	8.17

	CDN1 Desc		GVD1 Desc		GVD1 Asc	
	Rg Bias [cm]	Dat Bias [µs]	Rg Bias [cm]	Dat Bias [µs]	Rg Bias [cm]	Dat Bias [µs]
isardSAT DD - TUC DD	0.82	9.96	1.12	9.49	0.53	-7.13
isardSAT FF - Aresys FF	0.12	-0.91	0.44	0.46	-0.03	-1.84

Range & Datation Bias Summary

	CDN1 Desc				GVD1 Desc				GVD1 Asc			
	Rg Bias [cm]		Dat Bias [µs]		Rg Bias [cm]		Dat Bias [µs]		Rg Bias [cm]		Dat Bias [µs]	
	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std
CLS DD MOE PDAP	0.55	1.37	32.92	12.38	0.14	1.32	40.02	6.07	-3.33	1.40	53.14	6.92
TUC DD POE GPP	-0.46	1.26	-21.45	9.55	-1.12	1.08	-9.01	3.84	-3.81	1.20	-1.85	9.26
isardSAT DD POE GPP	0.36	1.23	-11.49	13.32	0.00	1.59	0.48	14.94	-3.28	1.05	-8.98	7.82
isardSAT FF POE GPP	0.64	1.27	**-2.19**	6.35	0.48	1.49	**-1.14**	14.73	-3.29	1.07	**4.60**	5.20
Aresys FF POE GPP	0.52	1.49	**-1.28**	6.20	0.04	1.61	**-1.60**	8.35	-3.26	1.06	**6.44**	5.47
CLS FF MOE PDAP	0.72	1.82	**-2.09**	7.98	1.86	0.62	**2.26**	3.19	-2.74	0.53	**7.28**	8.17

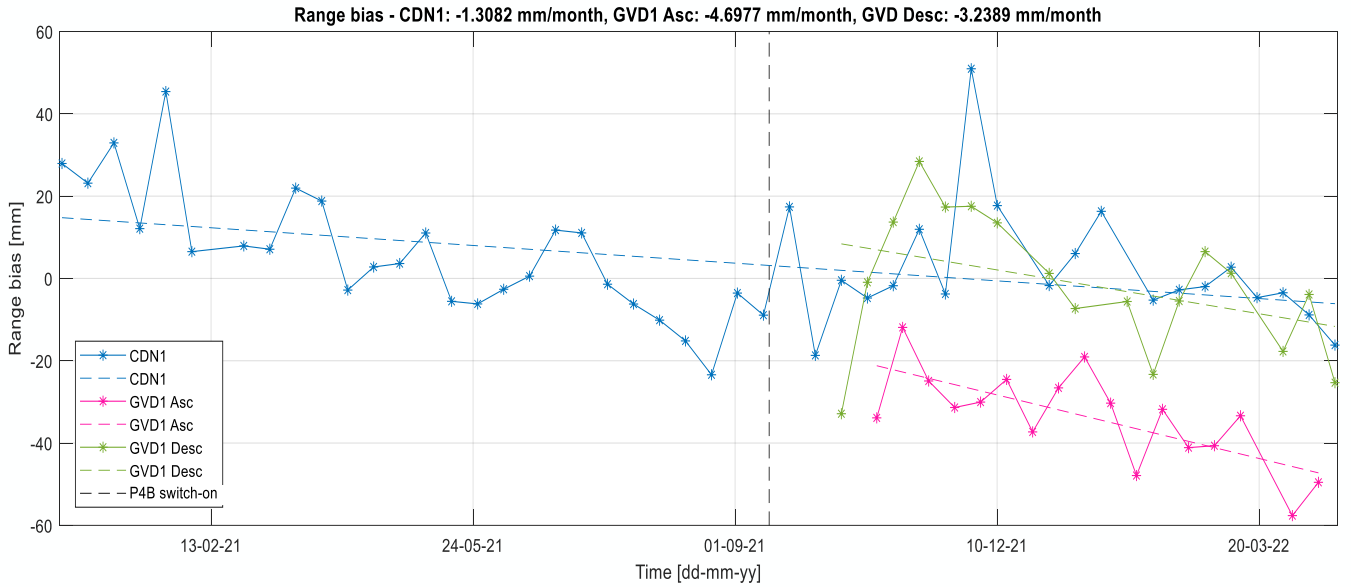
	CDN1 Desc		GVD1 Desc		GVD1 Asc	
	Rg Bias [cm]	Dat Bias [µs]	Rg Bias [cm]	Dat Bias [µs]	Rg Bias [cm]	Dat Bias [µs]
isardSAT DD - TUC DD	0.82	9.96	1.12	9.49	0.53	-7.13
isardSAT FF - Aresys FF	0.12	-0.91	0.44	0.46	-0.03	-1.84

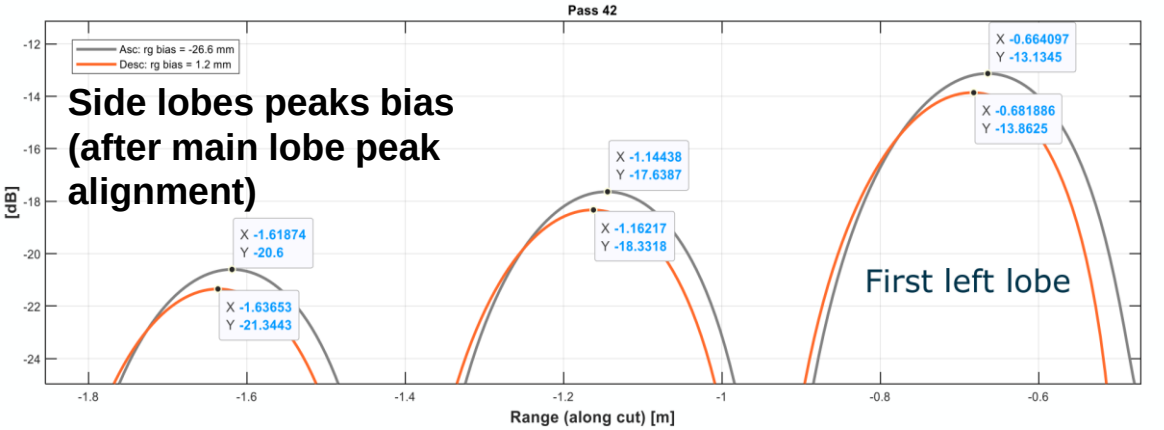
Range & Datation Bias Summary

	CDN1 Desc				GVD1 Desc				GVD1 Asc			
	Rg Bias [cm]		Dat Bias [µs]		Rg Bias [cm]		Dat Bias [µs]		Rg Bias [cm]		Dat Bias [µs]	
	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std
CLS DD MOE PDAP	0.55	1.37	**32.92**	12.38	0.14	1.32	**40.02**	6.07	-3.33	1.40	**53.14**	6.92
TUC DD POE GPP	-0.46	1.26	**-21.45**	9.55	-1.12	1.08	**-9.01**	3.84	-3.81	1.20	**-1.85**	9.26
isardSAT DD POE GPP	0.36	1.23	**-11.49**	13.32	0.00	1.59	**0.48**	14.94	-3.28	1.05	**-8.98**	7.82
isardSAT FF POE GPP	0.64	1.27	-2.19	6.35	0.48	1.49	-1.14	14.73	-3.29	1.07	4.60	5.20
Aresys FF POE GPP	0.52	1.49	-1.28	6.20	0.04	1.61	-1.60	8.35	-3.26	1.06	6.44	5.47
CLS FF MOE PDAP	0.72	1.82	-2.09	7.98	1.86	0.62	2.26	3.19	-2.74	0.53	7.28	8.17

	CDN1 Desc		GVD1 Desc		GVD1 Asc	
	Rg Bias [cm]	Dat Bias [µs]	Rg Bias [cm]	Dat Bias [µs]	Rg Bias [cm]	Dat Bias [µs]
isardSAT DD - TUC DD	0.82	9.96	1.12	9.49	0.53	-7.13
isardSAT FF - Aresys FF	0.12	-0.91	0.44	0.46	-0.03	-1.84

Range Bias Anomaly

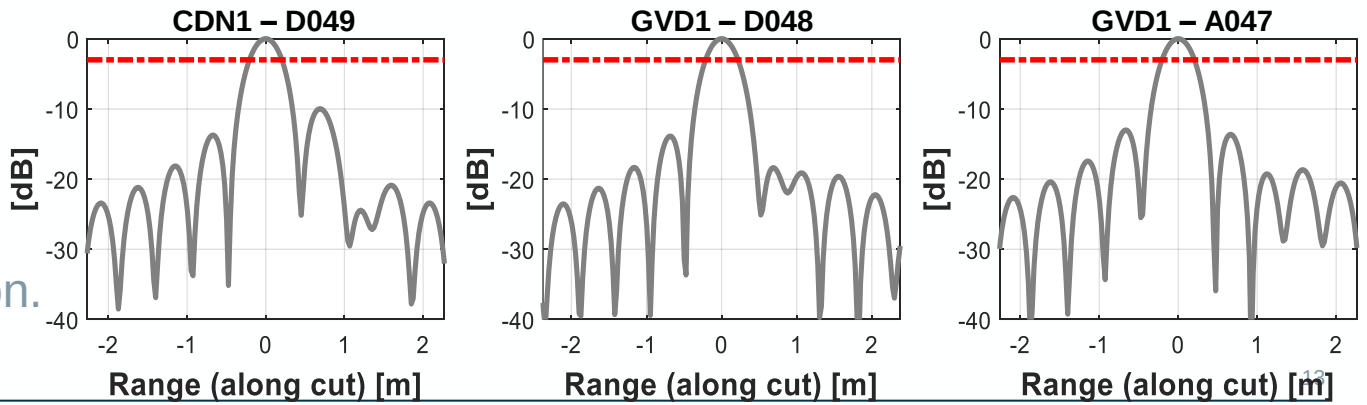




	CDN1-D – GVD1-D	CDN1-D – GVD1-A	GVD1-D - GVD1-A
Side lobe #1	13.8 mm	-7.0 mm	-20.8 mm
Side lobe #2	13.7 mm	-5.1 mm	-18.7 mm
Side lobe #3	12.7 mm	-5.3 mm	-17.9 mm

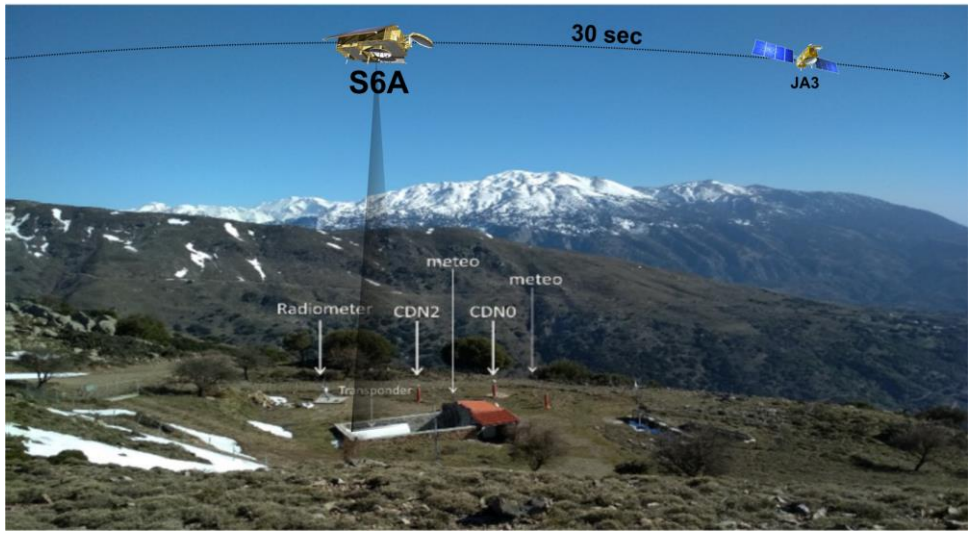
Side lobes peaks position statistics

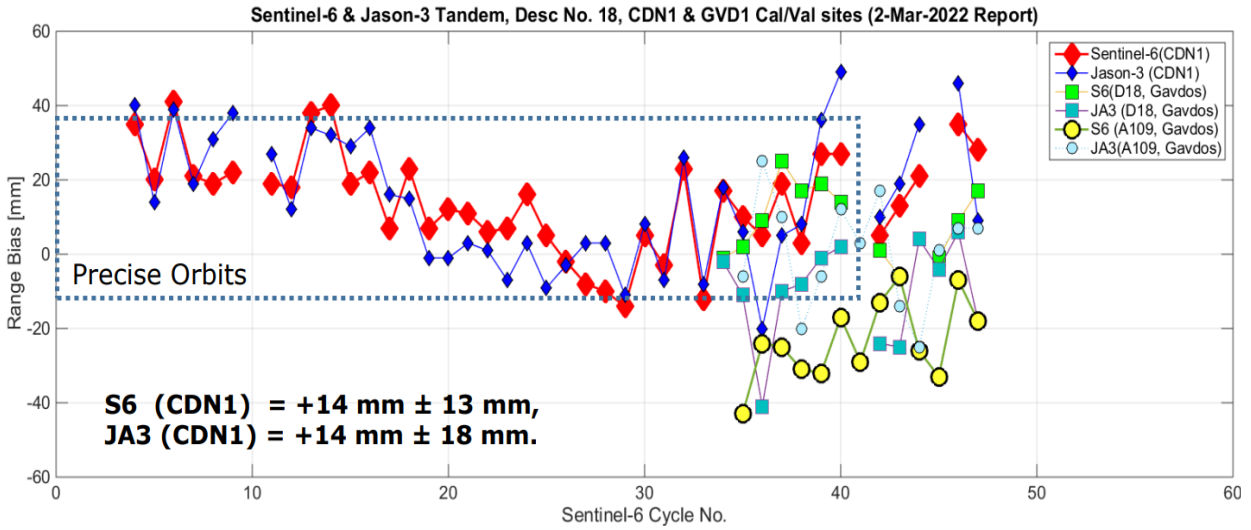
- Range bias anomaly recently observed in GVD1 asc. passes w.r.t. GVD1 and CDN1 desc. Passes,
- Collaborative investigation, dedicated meetings, analysis on several fronts,
- Not a rigid shift while IRF distortion,
- Waiting for effects after transponder signal isolation.

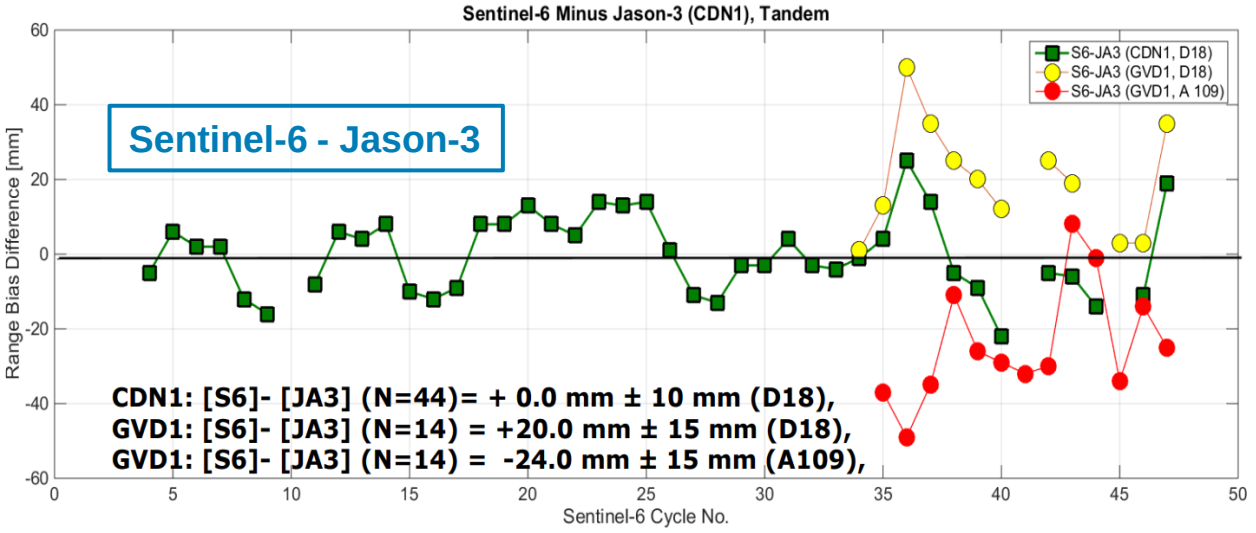


Sentinel-6 – Jason-3 in Tandem over CDN1 & GVD1

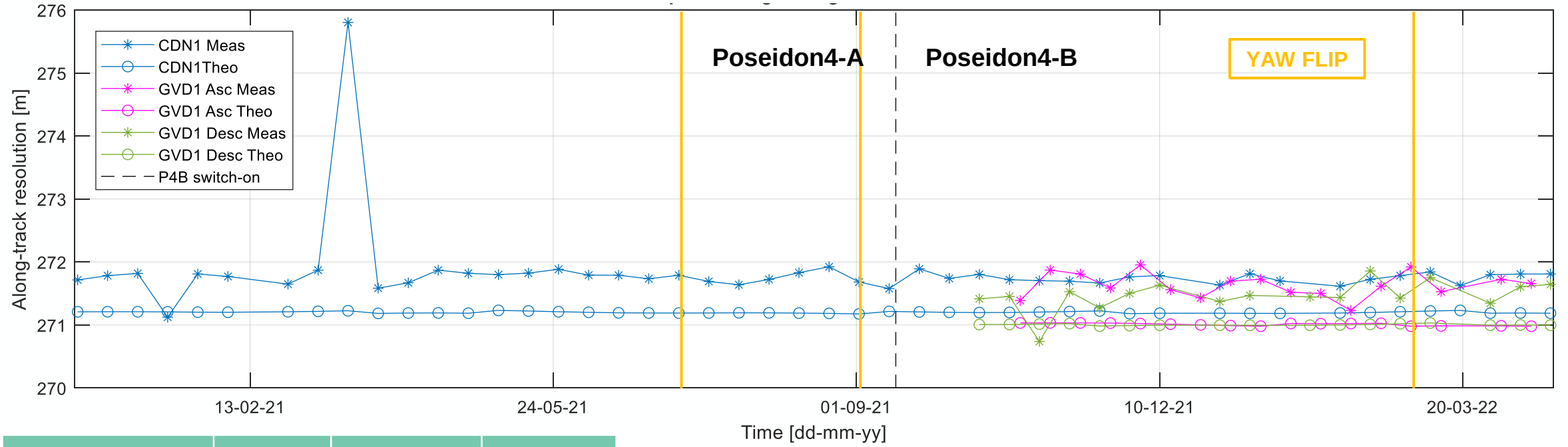
- Jason-3 was the reference mission for ocean altimetry until cycle 51 (April 2022),
- Jason-3 s 30 seconds ahead Sentinel-6,
- Comparison performed by Space Geomatica & Technical University of Crete,
- Delay Doppler (low resolution) processing,
- Fluctuations caused by Jason-3 implementing yaw steering.



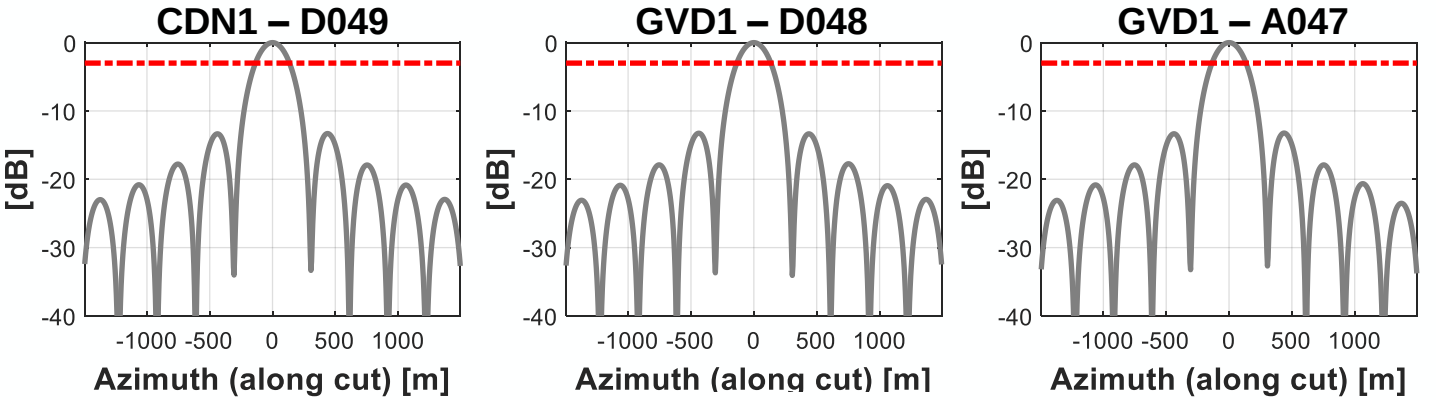




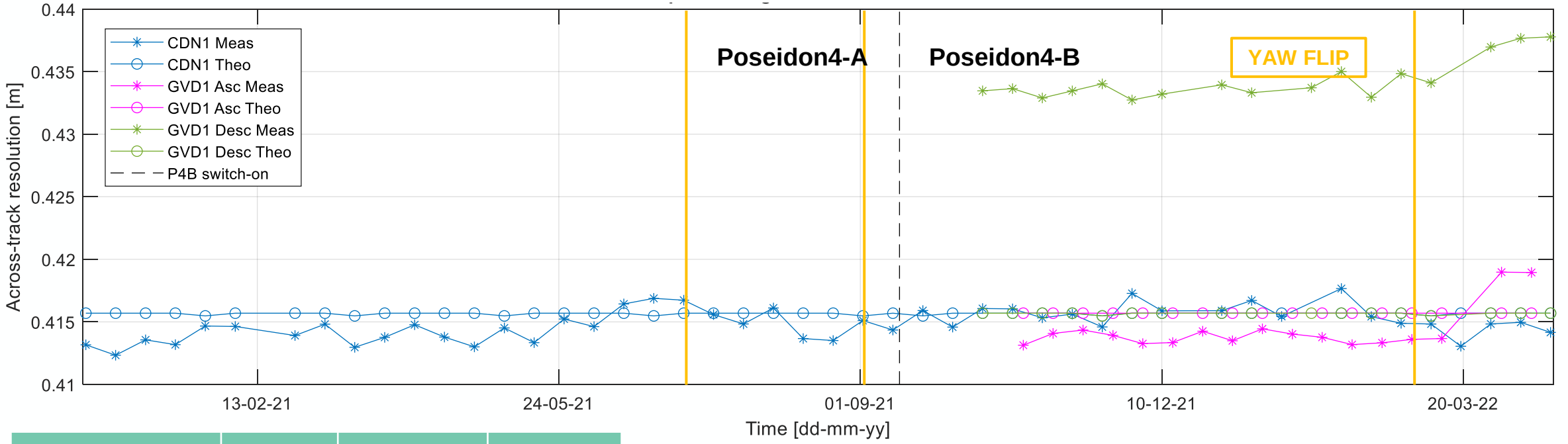
DD PTR – Azimuth Resolution



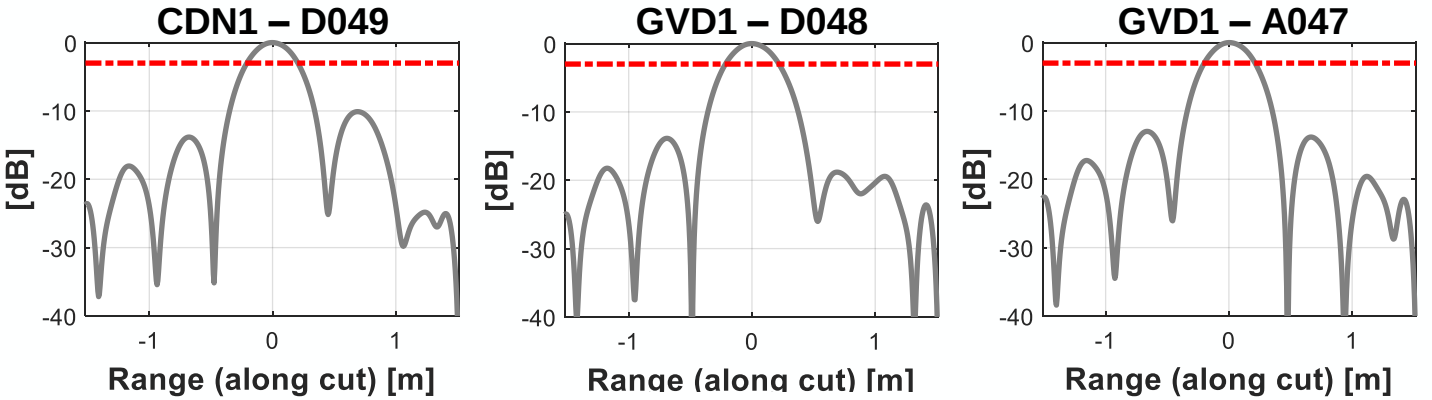
	CDN1	GVD1 Desc	GVD1 Asc
Average resolution [m]	271.826	271.463	271.630
STD resolution [m]	0.605	0.239	0.195
Average error [m]	0.627	0.461	0.621



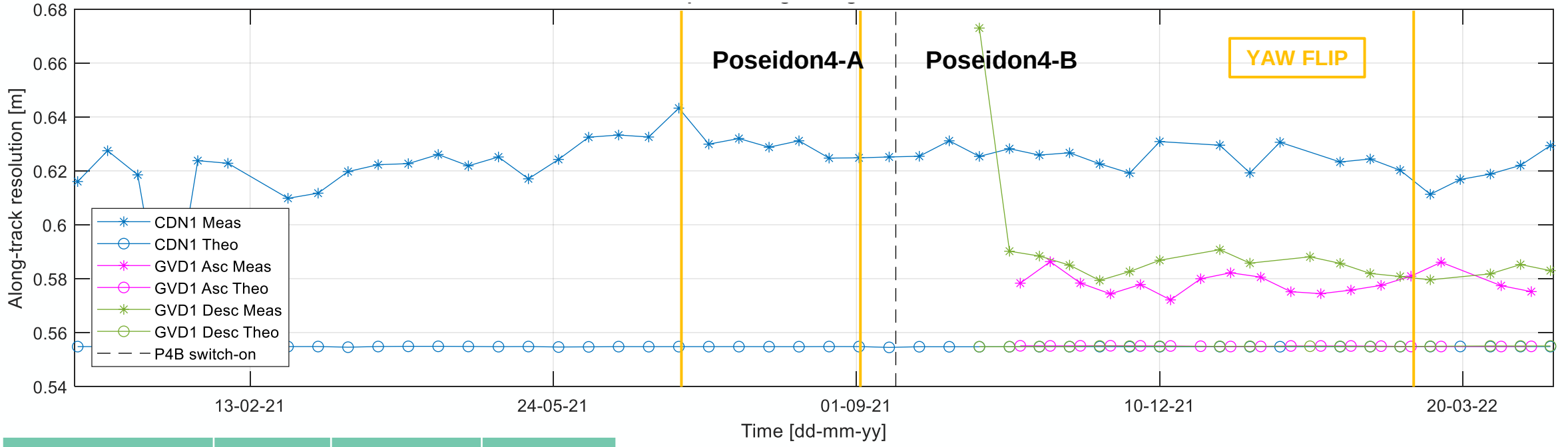
DD PTR – Range Resolution



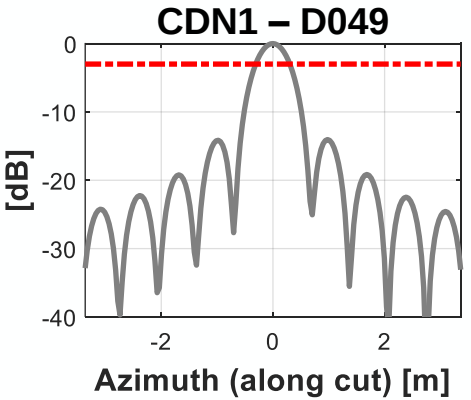
	CDN1	GVD1 Desc	GVD1 Asc
Average resolution [m]	0.415	0.434	0.414
STD resolution [m]	0.001	0.002	0.002
Average error [m]	-0.001	0.019	-0.001

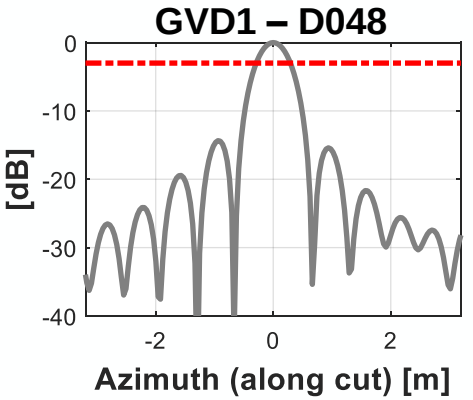


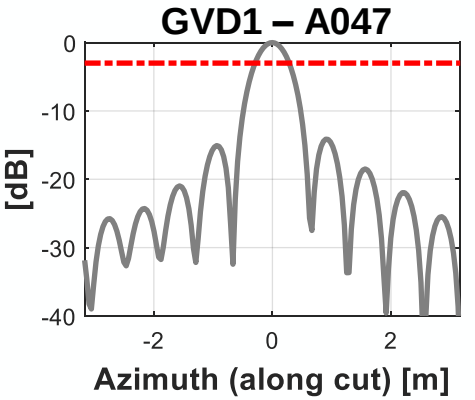
FF PTR – Azimuth Resolution



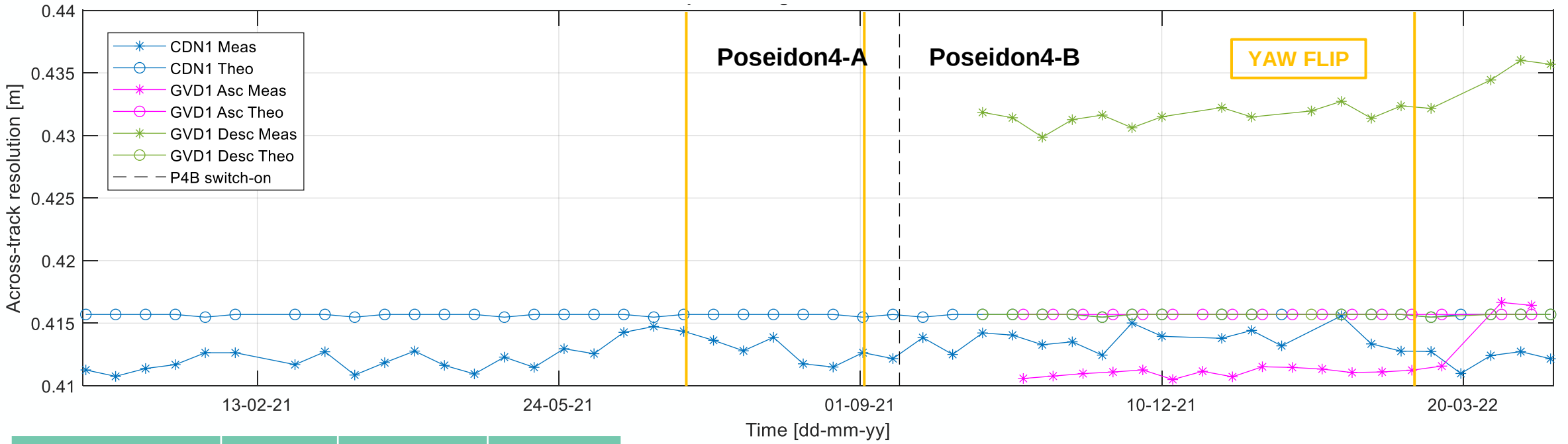
	CDN1	GVD1 Desc	GVD1 Asc
Average resolution [m]	0.623	0.590	0.578
STD resolution [m]	0.011	0.022	0.004
Average error [m]	0.068	0.035	0.023



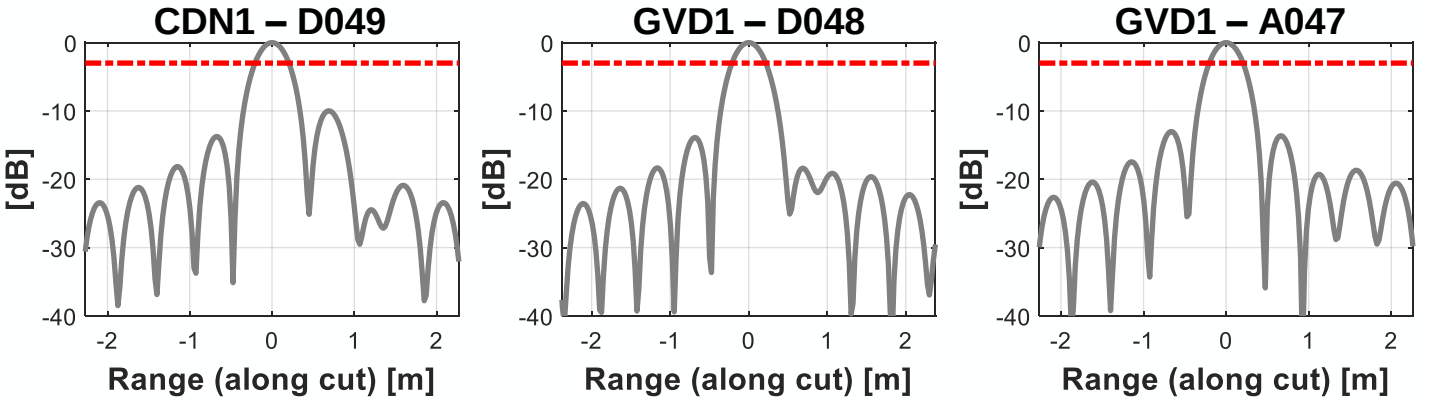




FF PTR – Range Resolution

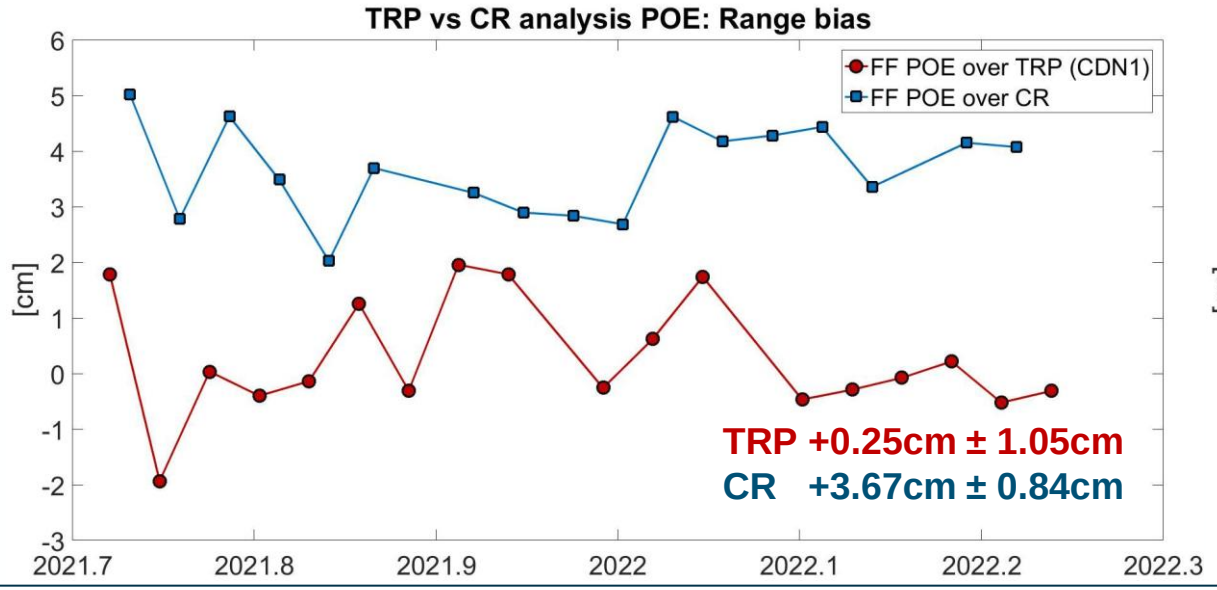


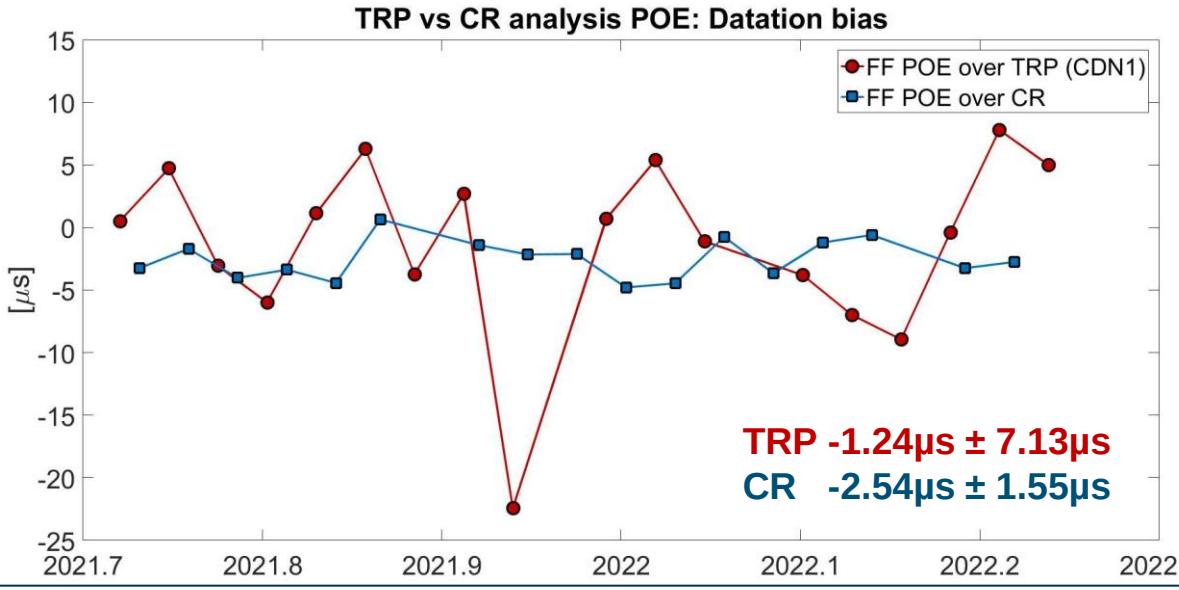
	CDN1	GVD1 Desc	GVD1 Asc
Average resolution [m]	0.413	0.432	0.412
STD resolution [m]	0.001	0.002	0.002
Average error [m]	-0.003	0.017	-0.004



Corner Reflector Results

- **Ca**libration using **Po**int **Ta**rgets (CaPoTa),
- Analysis performed by isardSAT,
- Comparable results w.r.t. Transponder,
- Long term stability and good performance/cost ratio.
- **Poster (Day 2) -> *A Trihedral Corner Reflector to Support Sentinel-6 Radar Altimeter External Calibration Using VHR FFSAR Algorithms,* Adrià Gómez Olivé et al., isardSAT**

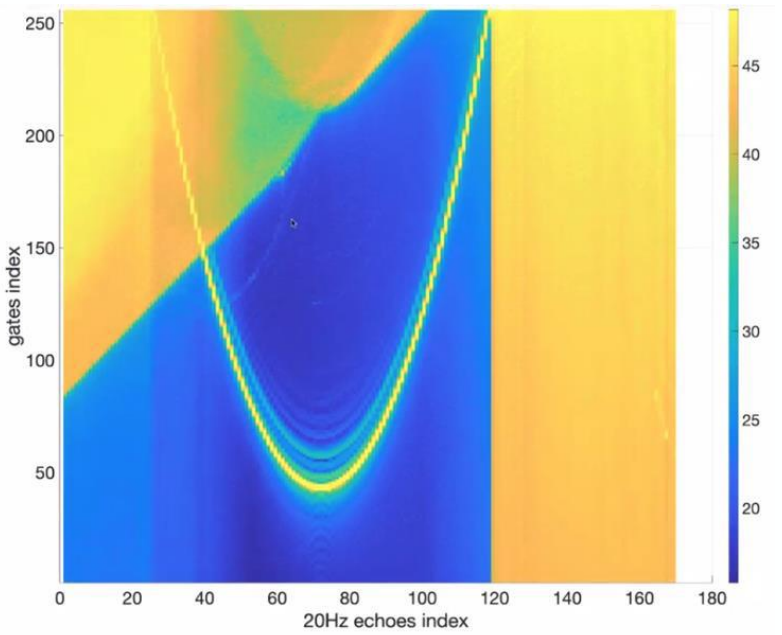




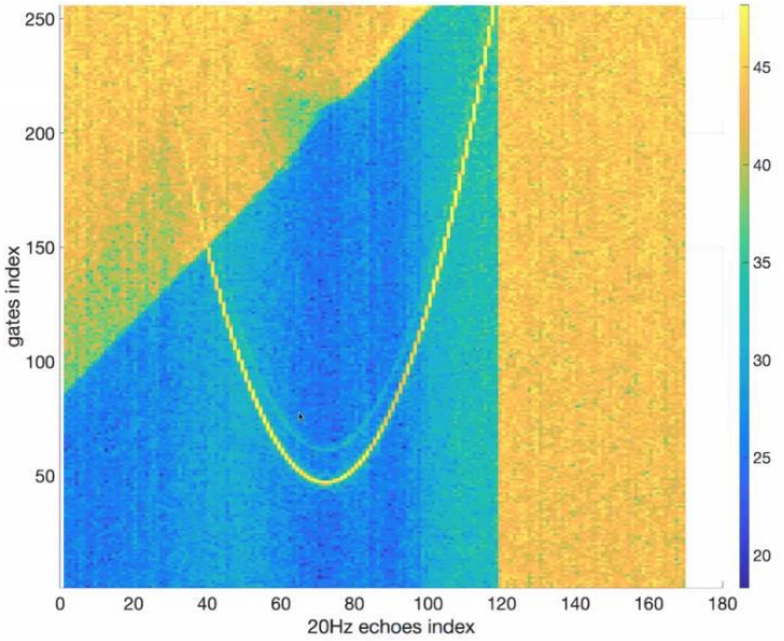
Santa Catalina Results

- Passes over JPL Transponder analysed by isardSAT
- First Sentinel-6 pass on the 14 of April 2022,
- Performances are under evaluation,
- Echoes from Ku and C band were properly acquired by Sentinel-6.

Measured waveforms Ku-Band in dB scale



Measured waveforms C-Band in dB scale



S6 TPX Group: Lessons Learned

- Convened by ESA for its contribution to Sentinel-6 Cal/Val.
- Turned out to be a winning strategy.
- Diverse institutions contribute in different ways to continuous monitoring of Sentinel-6.
- Periodical meetings.
- Results produced independently shared & Compared.
- Unexpected issues quickly identified & discussed.
- The number of infrastructures available provide Reliable & Redundant capabilities.