DORIS Antenna Phase Centre Offset (PCO): General considerations and Focus on Sentinel-3 Satellites

Hugues Capdeville[1], Olivier Dumond[2]
[1]Orbitography/Localization dept manager, [2]DORIS project manager
[1]*CLS*, [2]*CNES*

IN PARTNERSHIP WITH

Content

IDS Workshop

General considerations about PCO

Definitions
Focus on Phase Centre Offset for the DORIS Antenna
Phase Centre Variation as a function of azimuth and elevation
Phase Centre Variation as a function of temperature
Measurement Error related to PCO / CoP
CoP & ARP values in calibration plans (CNES reference document)

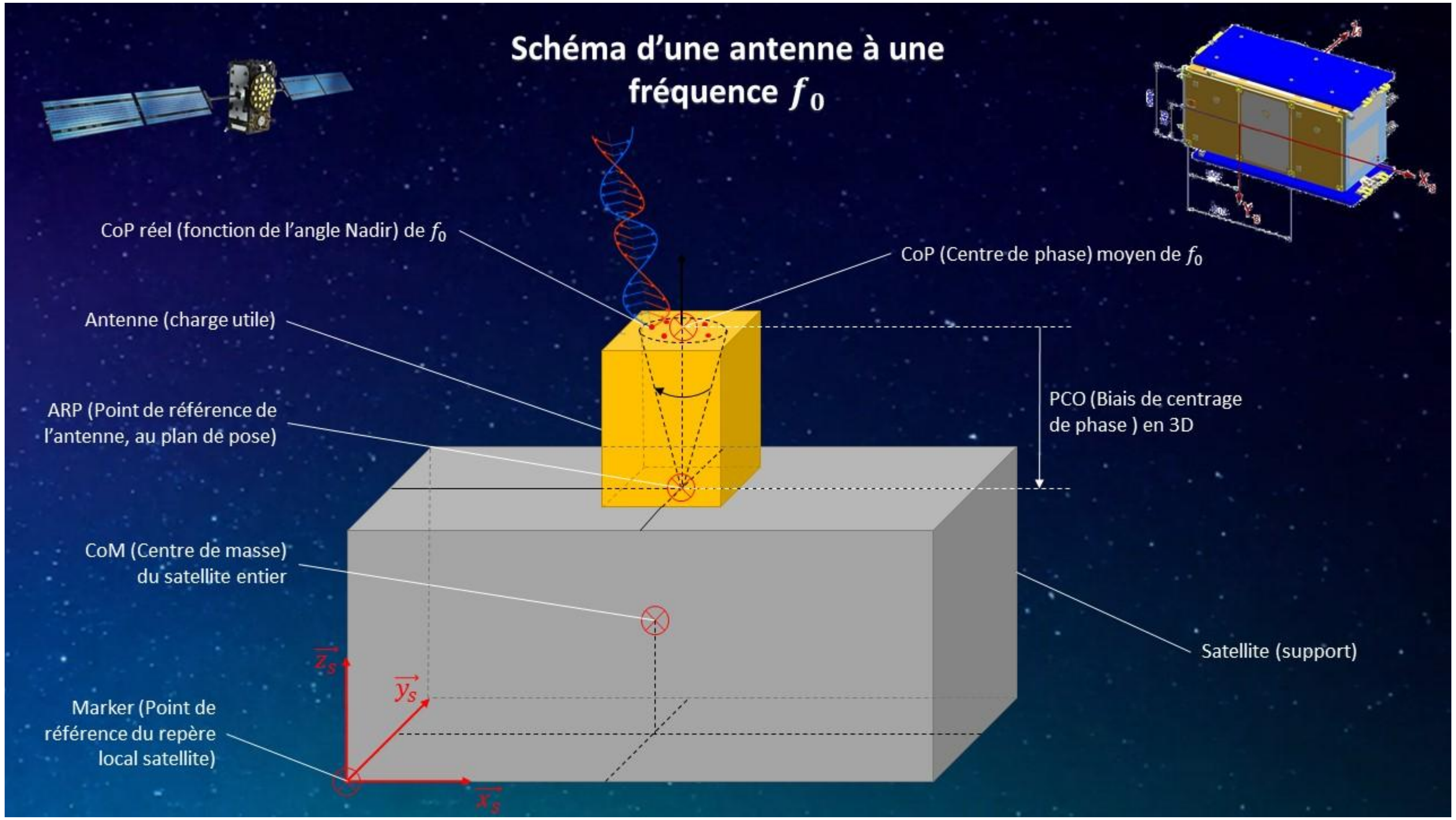
Impact of Updated CoP Values on Orbit, Scale Factor, and Geocenter for Sentinel-3 Satellites

Conclusion

Definitions

IDS Workshop

- **CoP** = Center Of Phase, The point from which the signal is emitted (depends on the signal pointing direction relative to the Nadir direction).
- **ARP** = Antenna Reference Point (ARP), the point where the antenna is physically attached to a planar support.
- **PCO** = Phase Center Offset (PCO), the 3D distance between the average Phase Center (CoP) of a frequency and the Antenna Reference Point (ARP) of the antenna (calculated by minimizing the CoP_average/ARP distance).
- **PCV** = Phase Center Variation (PCV), defined as the variation of the Phase Center (CoP).



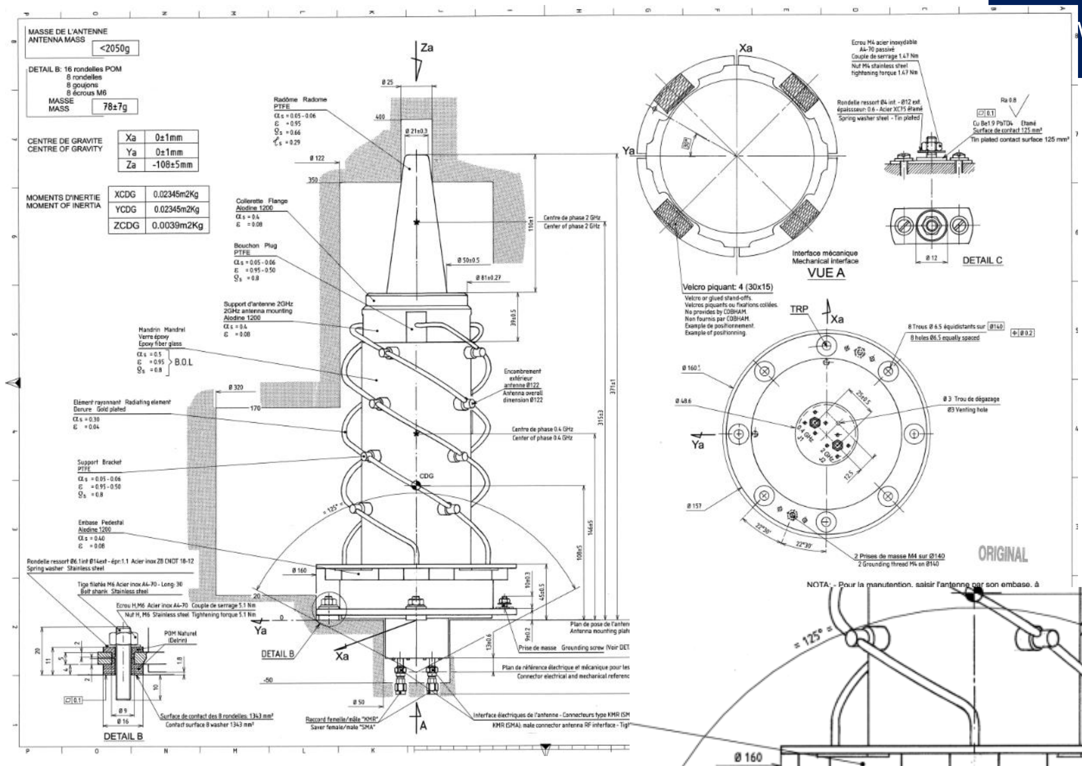
Extract from GNSS basis training - CNES

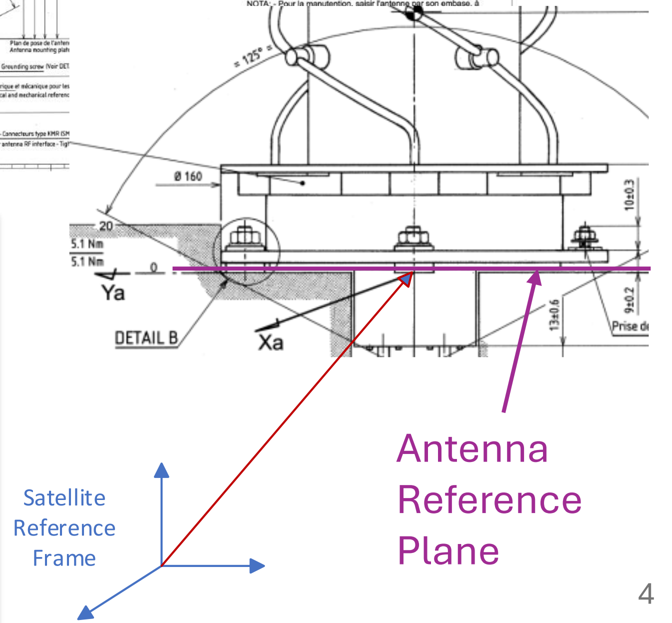
Focus on CoP / PCO for the DORIS Antenna

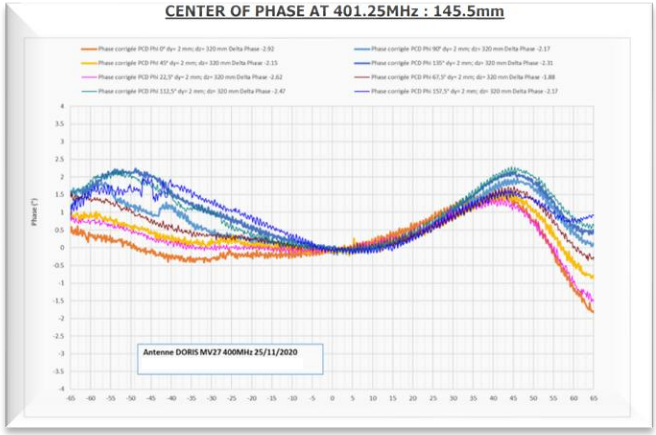
- **PCO (/ARP)** is measured by the manufacturer:
  - In outdoor test facility range
  - At ambient temperature and pressure
  - Given in the antenna reference frame

- **PCO (/SatRF)** has to be calculated with the position of ARP in the Satellite Reference frame:
  - Position « Satellite Reference frame » to « Antenna Reference Point » + PCO (/ARP)

- One recent concern was about the possible error in the ARP considered :
  - ARP is the mounting plane that is not on the antenna itself, it is below the mounting flange separated by an insulating washer of height <u>4 mm</u>







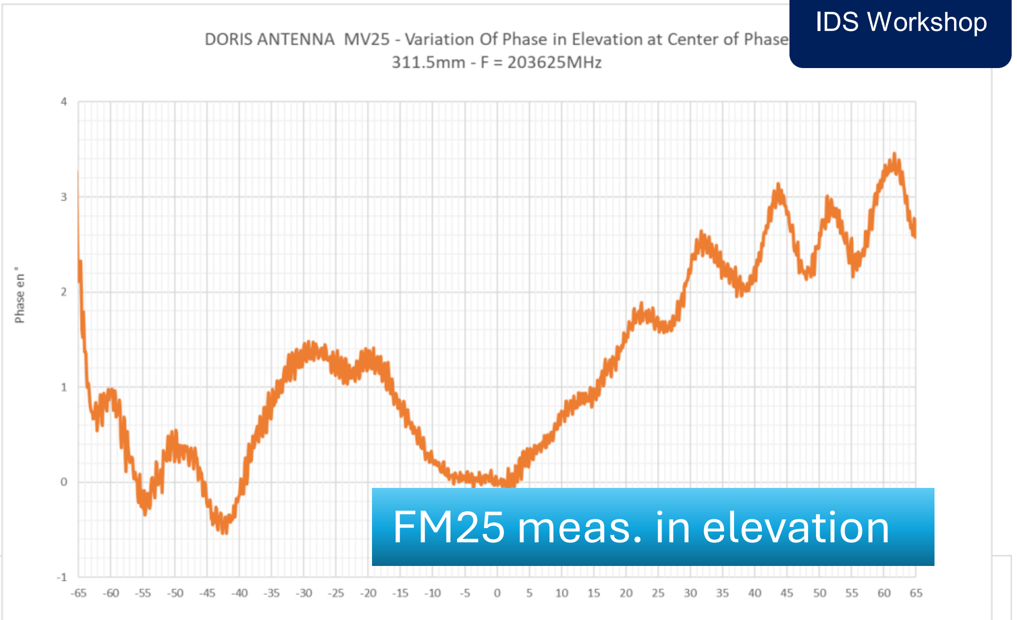
Phase Centre Variation as a function of azimuth and elevation

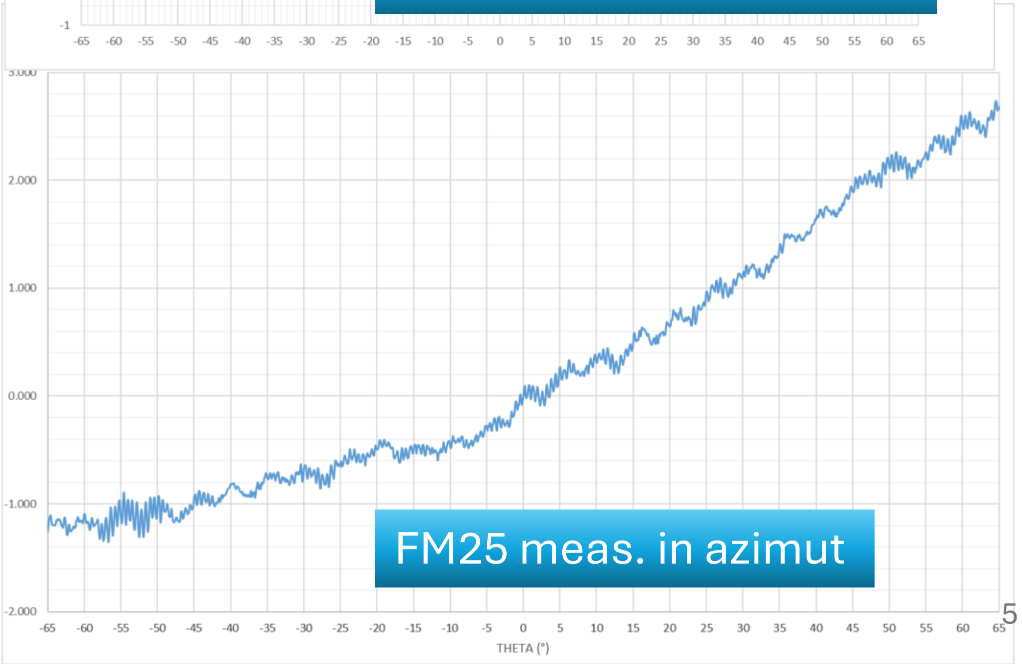
The phase linearity in azimuth and elevation is characterized.

$\pm$ **3 degrees** of variation correspond to:

@ 400 MHz — *$\pm$ 6.2 mm in distance*

@ 2 GHz — *$\pm$ 1.2 mm in distance*





PCV as a function of temperature

Not done by the DORIS Antenna provider and difficult to do as coupling thermal and anechoic chambers is tricky

Thermo-elastic analysis can give an evaluation of the deformation of the radiating element and one can deduce geometrically the shift of the PCO (under analysis for Genesis)

Previous thermal analysis showed very little deformation:

ΔPCO in mm	400 MHz	2 GHz
+ 20 °C (ref.)	0	0
+ 85 °C	+ 0.75	+ 0.14
- 56 °C	- 0.88	- 0.16
+ 99 °C	+ 0.91	+ 0.17

Measurement Error (1/2)

IDS Workshop

CoP / PCO

Strongly impacted by the near surrounding environment setup (measurement mechanical interface / mast)

So strongly dependent to the antenna environment integration (location on the satellite = but never tested at satellite level so far)

Today with manufacturer test facility, PCO measurement error is:
± 2 mm for S-band
± 5 mm for UHF band (UHF nominal measurement ponderation is 1/5)

PCV / Phase linearity in azimuth / elevation

Today with manufacturer test facility, phase linearity meas. error is:
± 1.8 / 1.5 mm for S-band
± 3.8 / 3.2 mm for UHF band (UHF nominal measurement ponderation is 1/5)

Courtesy: THALES

Measurement Error (2/2)

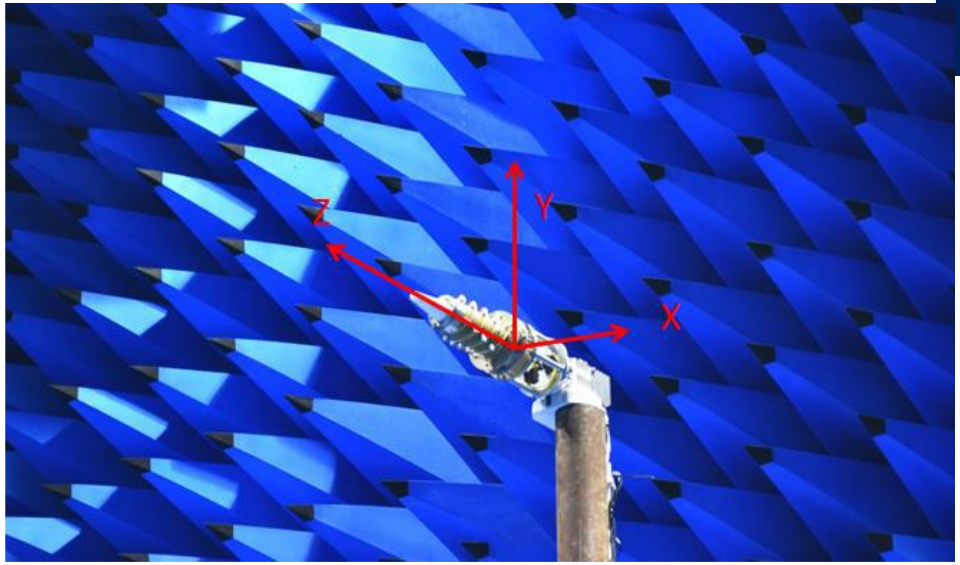
CoP / PCO

For Genesis with CNES test facility (CATR)

Two main contributors on the PCO determination

1. Field quality (in phase) within the quiet zone
   - ➔ Leads to ± 0.5 mm for the S-band
   - ➔ To be investigated for the UHF-band (± 5 mm TBC)
2. Geometric measurement to express PCO in the measurement coordinate system
   - ➔ Typical value ± 2 mm (independent from the band)

This contribution can be strongly decreased (expected of a factor 10 min) by implementing a more precise positioning system with laser (under analysis)



PCV, Phase linearity azimuth / elevation

To be evaluated

CoP & ARP values in calibration plans (CNES reference document)

	Version	S3A	S3B	S3C	S3D	SWOT	S6A	S6B
Same CoP for all versions	4.5 / 4.4 / 4.3 / 4.2 / 4.1 / 4.0	0 ; 0 ; 150 (UHF) 0 ; 0 ; 316 (S)	0 ; 0 ; 141 0 ; 0 ; 314	0 ; 0 ; 141 0 ; 0 ; 312	0 ; 0 ; 141 0 ; 0 ; 311.5			
ARP changed >4.4	4.5 / 4.4 4.3 / 4.2 / 4.1 / 4.0	1569 ; 73 ; 755 1570 ; 73 ; 760	1569 ; 73 ; 755 1570 ; 73 ; 760	1569 ; 73 ; 755 1570 ; 73 ; 760	1569 ; 73 ; 755 1570 ; 73 ; 760			
CoP changed >1.1 (initial value FM20/S3A)	1.4 / 1.3					0 ; 0 ; 145 0 ; 0 ; 311		
	1.1					0 ; 0 ; 150 0 ; 0 ; 316		
ARP changed >1.4	1.4 1.3					-1 ; 544 ; 4639 0 ; 461; 4764		
Same CoP / ARP values for all versions	10 / 11 / 12						0 ; 0 ; 143 0 ; 0 ; 312	0 ; 0 ; 145.5 0 ; 0 ; 313.5
	10 / 11 / 12						1625 ; 400 ; 685	1625 ; 400 ; 685
	CoP /SRF 'UHF' CoP /SRF 'S'	1569 ; 73 ; 905 1568 ; 73 ; 1071	1569 ; 73 ; 896 1569 ; 73 ; 1069	1569 ; 73 ; 896 1569 ; 73 ; 1067	1569 ; 73 ; 896 1569 ; 73 ; 1066.5	-0.2 ; 544.6 ; 2631.1 -0.2 ; 544.6 ; 2797.1	1625 ; 400 ; 828 1625 ; 400 ; 997	1625 ; 400 ; 830.5 1625 ; 400 ; 998.5

/!\/!\!\ For SWOT /!\/!\/!\
Karin module Ref frame considered
ARP /KMSF = -0.2; 544.6 ; 2486.1

CoP /KMSF for SWOT

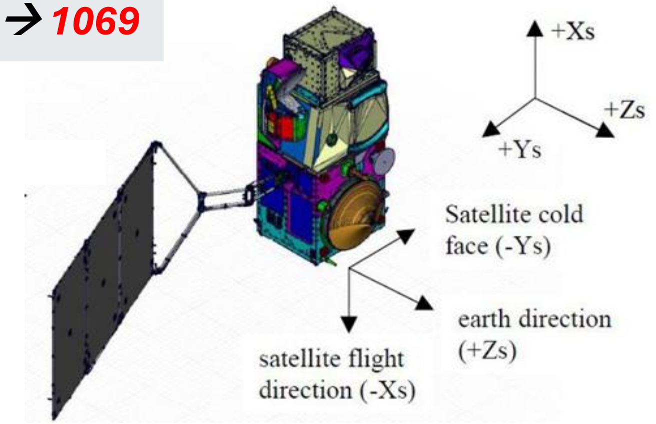
Impact of Updated CoP Values on Orbit, Scale Factor, and Geocenter for Sentinel-3 Satellites

Updated DORIS Antenna Phase Center position in the satellite reference frame:

DORIS CoP position	Sentinel-3A (in mm) X	Y	Z	Sentinel-3B (in mm) X	Y	Z
UHF (400 MHz)	*1570 → 1569*	*73*	*910 → 905*	*1570 → 1569*	*73*	*910 → 896*
S (2 GHz)	*1570 → 1569*	*73*	*1076 → 1071*	*1570 → 1569*	*73*	*1076 → 1069*

New CoP values:

- **For Sentinel-3A, ΔZ (2Ghz) = -5 mm**
- **For Sentinel-3B, ΔZ (2Ghz) = -7 mm**



DORIS data processing

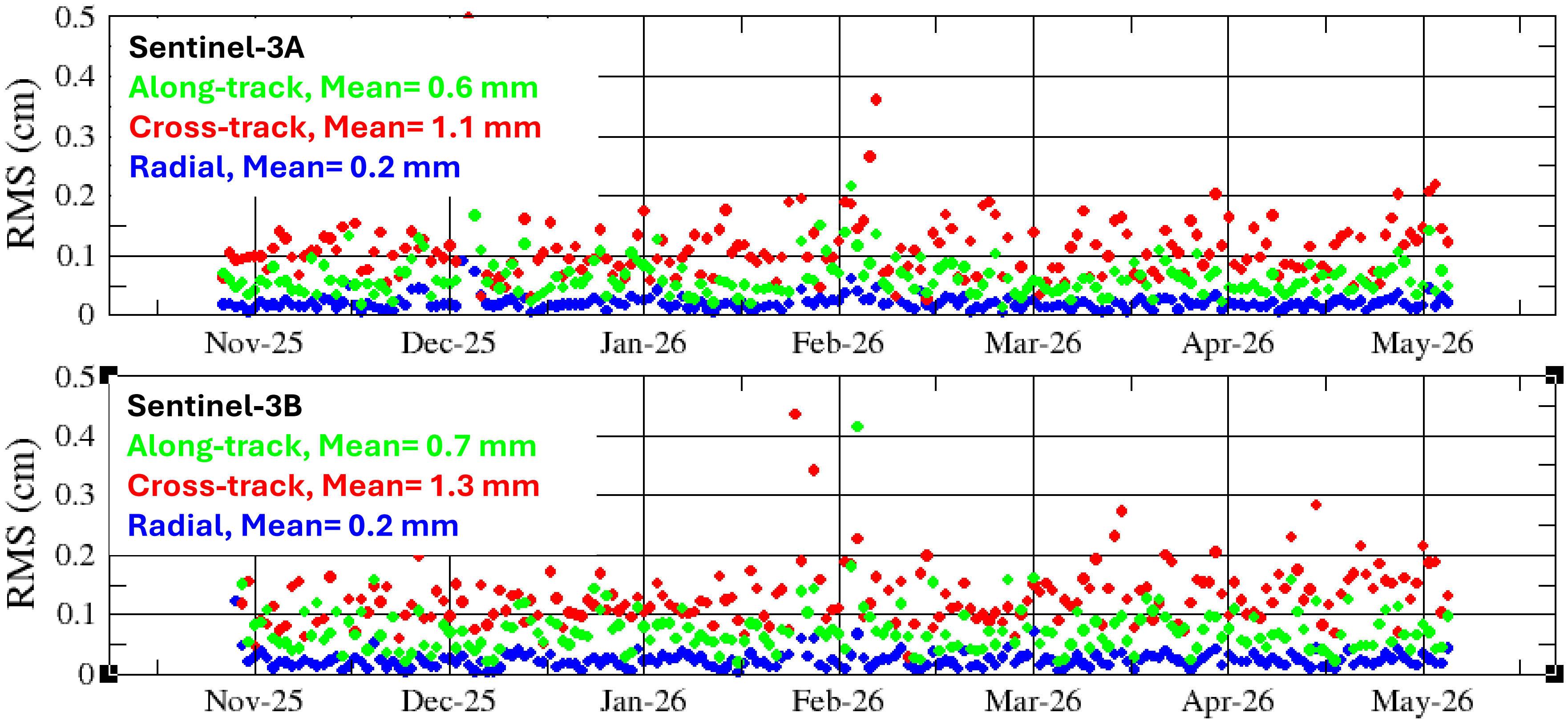
- 165 weeks of DORIS data processed (Feb. 19, 2022 – Apr. 25, 2026)
- Comparison between operational and updated series (new CoP values)

Impact of Updated CoP Values on Orbit, Scale Factor, and Geocenter for Sentinel-3 Satellites

IDS Workshop

Impact on the orbit

Orbit comparison between the operational and updated series (new CoP position values)



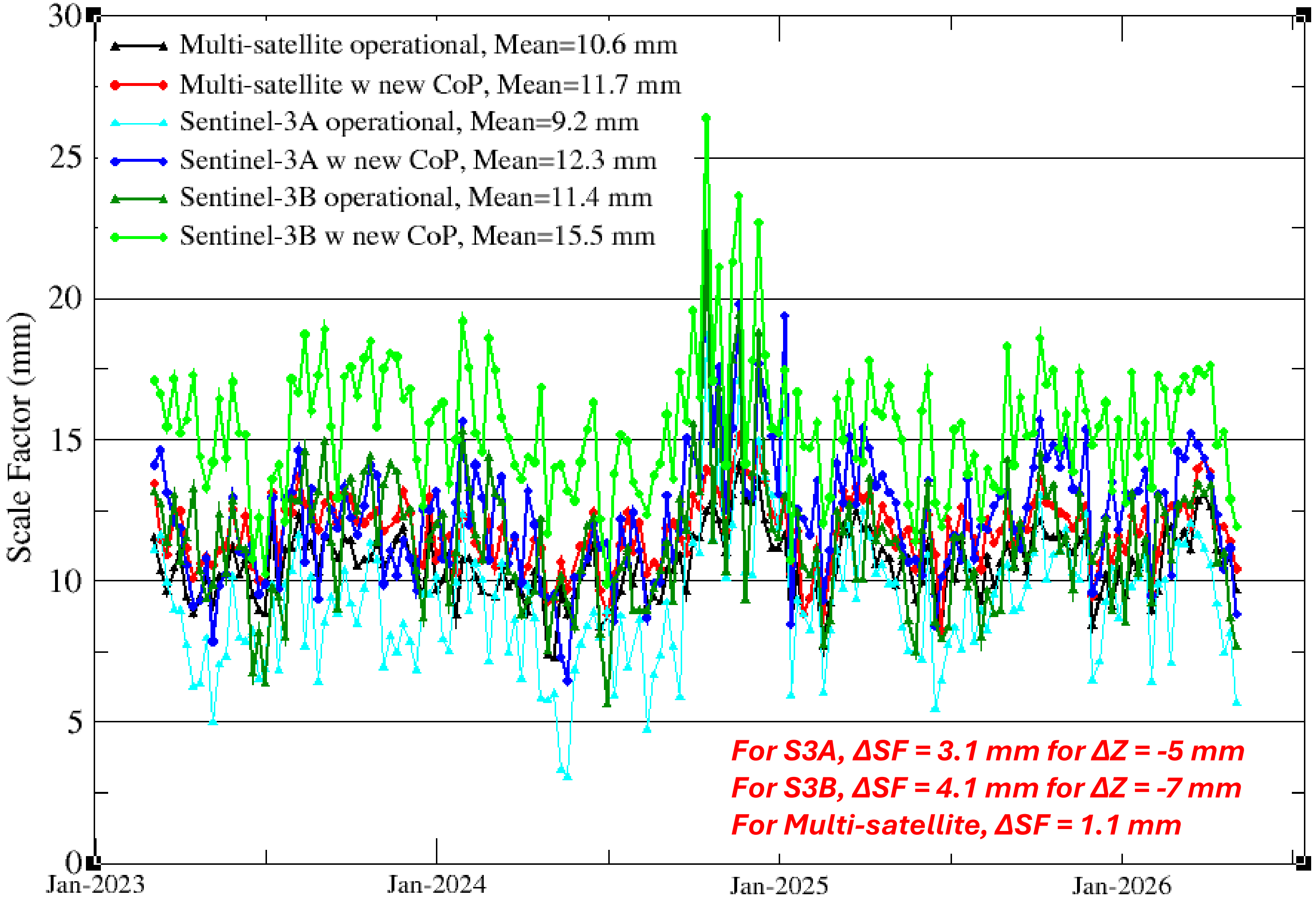
No significant impact and no systematic bias between the orbit solutions.

Impact of Updated CoP Values on Orbit, Scale Factor, and Geocenter for Sentinel-3 Satellites

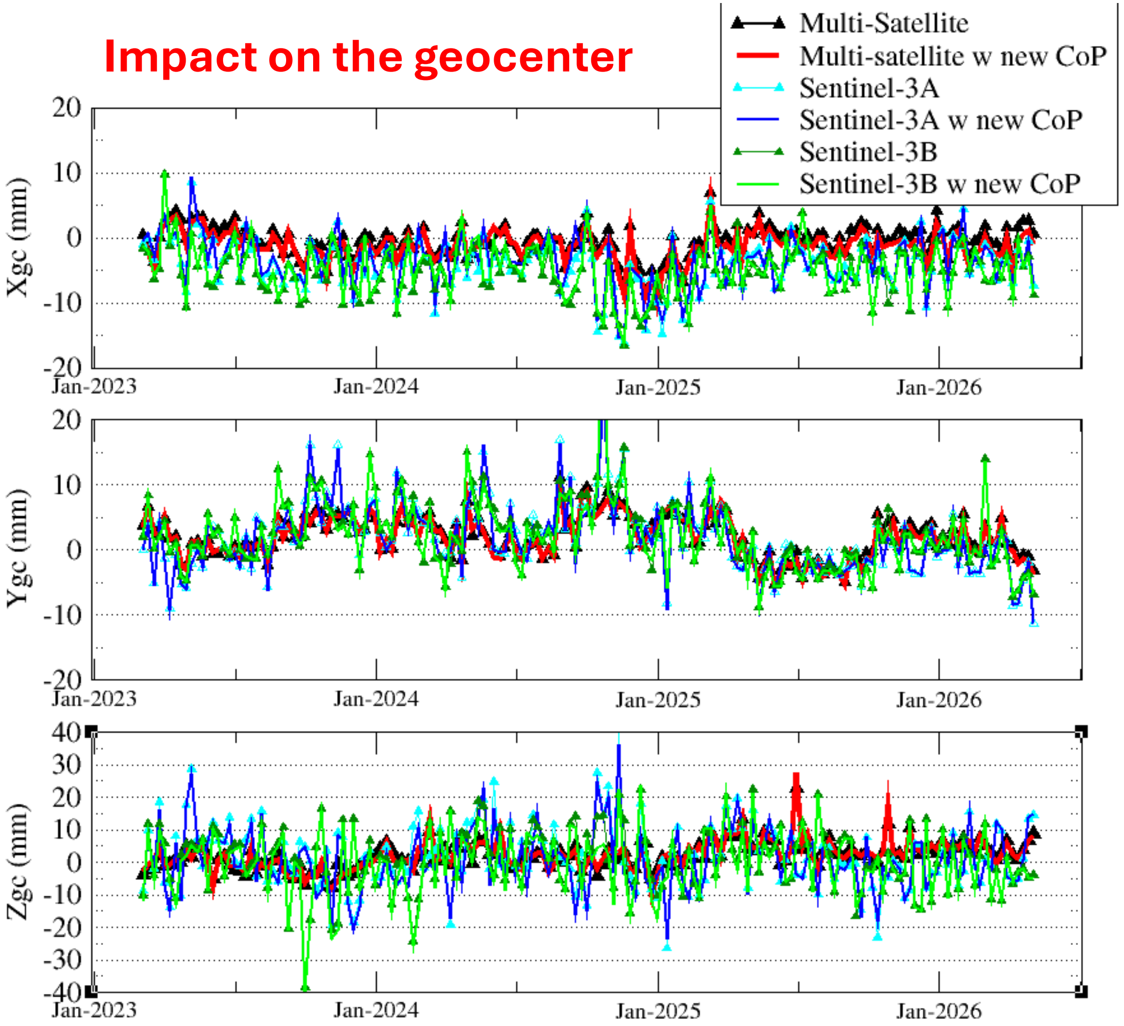
IDS Workshop

Comparison of each solution to DPOD2020

Impact on the scale factor (SF)



Impact on the geocenter



As expected, the impact mainly affects the scale factor, with no significant effect on the geocenter.

Conclusion

Characterizing the CoP/PCO (Center of Phase/Phase Center Offset) is crucial for enhancing performance in navigation, Precise Orbit Determination (POD), and geodesy.

Key Challenges:

- **Technical complexity** of the measurement.
- **Significant measurement errors**, which substantially contribute to the overall error budget.

Ongoing Efforts:

- **Reducing measurement errors** through the Genesis project, featuring another test facility and setup.

Future Considerations:

- **For next-generation antennas** (more compact designs), phase linearity performance is expected to decrease. Thus, it will be essential to accurately characterize this linearity to enable real time and post-processing corrections.
- **Improving the dissemination** of CoP/PCO values to support broader applications.