25 YEARS OF PROGRESS IN RADAR ALTIMETRY

COPERNICUS POD SERVICE ORBIT VALIDATION OF SENTINEL-3 MISSION

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ABSTRACT

Sentinel-3A is in orbit since two years now and the precise orbit determination (POD) is well established. The official orbit solutions from CNES and the **Copernicus POD Service** as well as other orbit solutions from several institutes, in particular from the members of the Copernicus POD QWG (Quality Working Group), are available. The orbit solutions are derived from different software packages, based on different models, arc lengths and parametrizations, and are computed with different observables. Some solutions are based on GPS observations only, some on DORIS observations only, and others are combined solutions. SLR measurements are mainly used for validation but might also be used in a combined orbit determination.

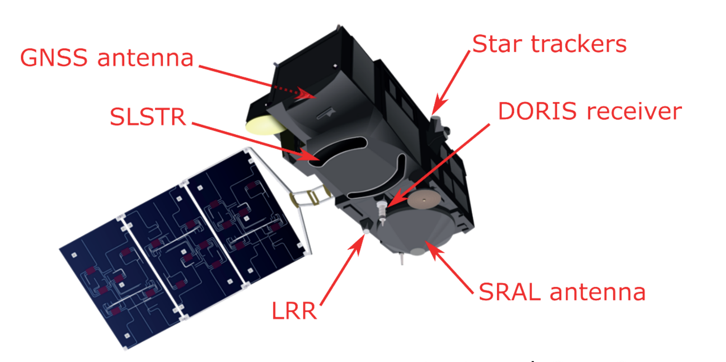
Correct knowledge of the antenna and reflector offsets is fundamental to guarantee the required orbit accuracy for the analysis of the radar altimeter measurements. The three observation techniques available on Sentinel-3A offer the opportunity to compare and validate the offsets of the SLR reflector and the GPS and DORIS antennas against each other. Offset estimates are available from different groups and from different approaches. Validation of these offsets is done based on the analysis of the manifold orbit solutions using original and updated coordinates.

This poster assesses the impact of three different POD configurations proposed by the CPOD QWG meeting, using the current POD SW of **Copernicus POD Service**.

INTRODUCTION – SENTINEL-3 MISSION

- **Sentinel-3** is an Earth Observation mission key to the Copernicus Programme, the European Programme for the establishment of a European capacity for Earth Observation.

- Since the launch of the **Sentinel-3A** satellite on February 2016, the mission accumulates more than 30 months of Precise Orbit Determination operations, reaching radial errors below the 1 cm barrier. Its twin, **Sentinel-3B**, joined to the mission on April 2018 and is operational since last August.



- The **Copernicus POD Service (CPOD)**, part of the Copernicus PDGS Ground Segment, is responsible for the generation of precise orbital products and auxiliary data files for their use as part of the processing chains of the PDGS.

- The CPOD Service is operated at GMV (Spain), except for the NRT products which are generated by the Sentinel-3 POD IPF (SW component) deployed at the Marine and Land PDGS centres.

- Members of the **Quality Working Group (QWG)** (e.g. ESOC, CNES, DLR, …) agree on a set of parameters characterizing the satellites' geometry and perform independent POD. This is then used for cross-validation of processing models and evaluation of orbital accuracies.

- **DLR** and **CNES** propose respective **changes in the Centre of Gravity (CoG)** and the **GNSS antenna Phase Center Offset (PCO)**. The **CPOD** has evaluated the impact of these two configurations against the nominal one using in all cases the **NAPEOS** software.

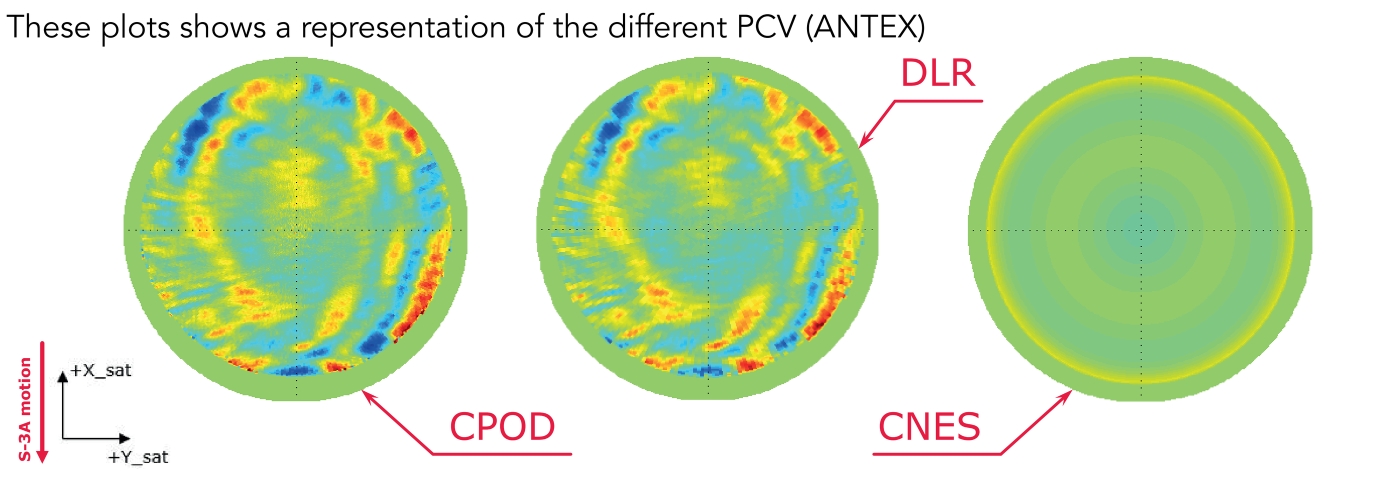
- This **poster** aims at presenting results on the orbital validation of **Sentinel-3A** using GPS, SLR and attitude data for the following time period: **September 1, 2017 – January 31, 2018**

POD SCENARIOS FOR VALIDATION

- The following table shows the three different POD configurations used

Parameter	Elements	CPOD conf	CNES conf	DLR conf
Software used		**NAPEOS**		
Arc length		32 hours		
Reference systems	Polar motion and UT1	IERS C04 08		
	Pole model	IERS 2010 Conventions		
	Precession/Nutation	IERS 2010 Conventions		
Gravity parameters	Gravity field (static)	EIGEN.GRGS.RL03.v2 (120x120)		
	Gravity field (time varying)	drift/annual/semi-annual piece wise linear terms up to degree/order 50		
	Atmospheric gravity	AGRA (20x20)		
	Other factors taken into account	Solid Earth, Ocean, Atmospheric, Earth Pole, Ocean Pole tides + Third bodies (Sun, Moon, Planets DE405)		
Surfaces forces and empiricals	Radiation Pressure model	box-wing model		
	Earth radiation	albedo and infra-red applied		
	Atmospheric density model	msise90		
	Radiation pressure coefficient	1 per arc		
	Drag coefficients	10 per day		
	1/rev empirical	2 sets per day (in along and cross track directions, constant/sine/cosine)		
GPS measurements	Relativity	IERS 2010		
	Sampling	10 sec		
	Observations	iono-free linear combinations of phase and pseudo-range measurements		
	Weight	0.8 m (pseudo-range) / 10 mm (carrier-phase)		
	Elevation angle cut-off	7 degrees		
CoG (on 1 Oct 2017)	X ; Y ; Z	1.494 ; 0.219 ; 0.009	1.494 ; 0.209 ; 0.009	1.494 ; 0.209 ; 0.009
GPS ANTEX	Filename	sen08_2006.atx	s3a_CNES_COPPOD.atx	s3a_DLR.atx
	X_ant ; Y_ant ; Z_ant (mm)	0 ; 0 ; 68	0 ; 0 ; 80	0 ; 0 ; 67

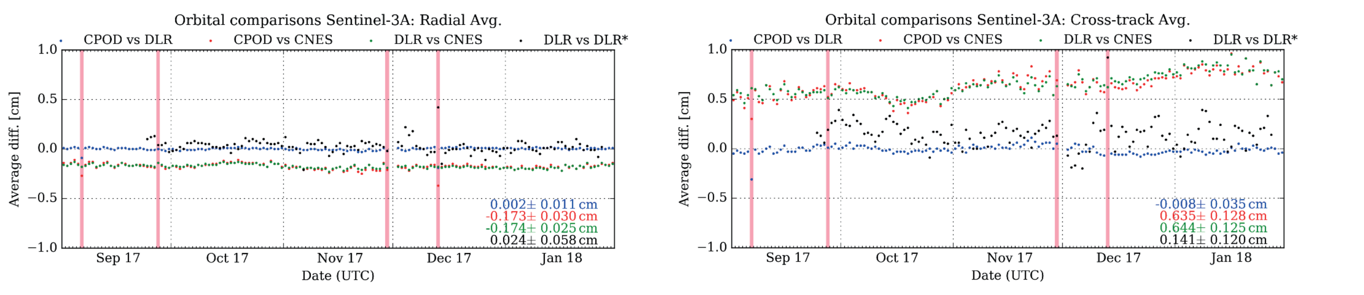
- These plots shows a representation of the different PCV (ANTEX)

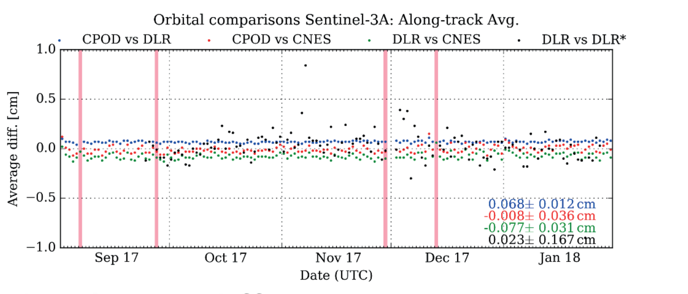


VALIDATION OF ORBITAL ACCURACY

The following plots shows the orbital cross-comparisons in terms of biases and RMS. The fourth solution (DLR*) represents a DLR solution, using GHOST POD SW, DLR configuration and Integer Ambiguity Fixing.

Orbital Biases

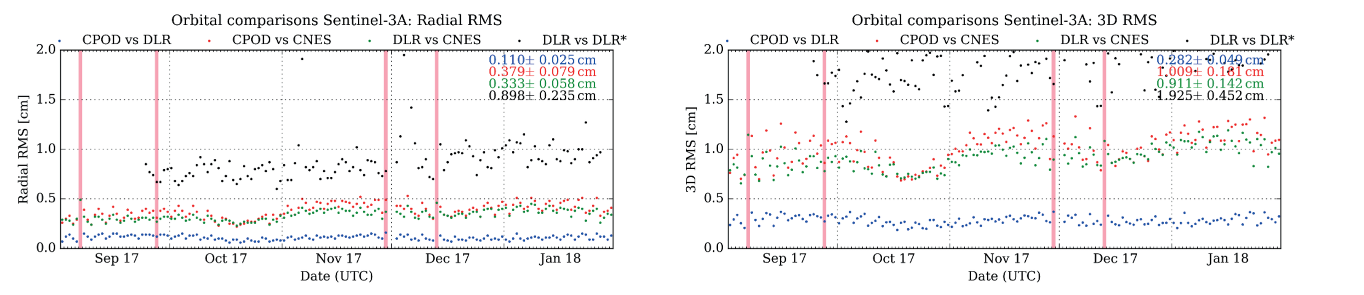




Biases found wrt CNES configuration

- Radial direction 0.17 cm
- Along-track direction 0.07 cm
- Cross-track direction **0.64 cm**

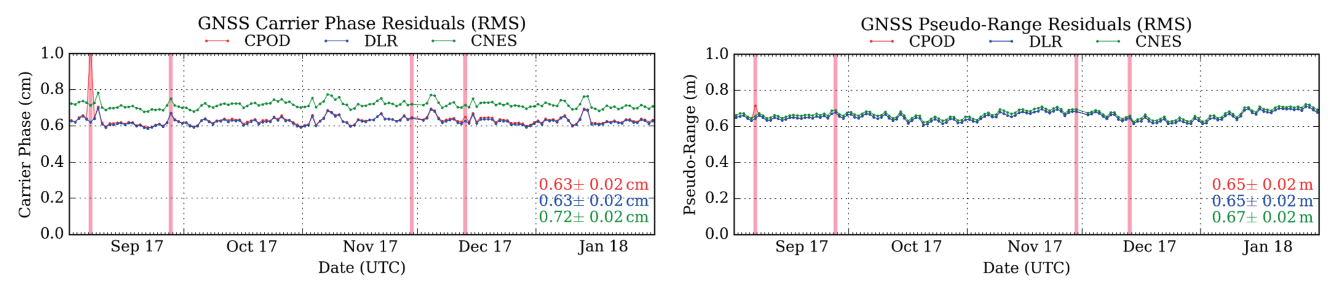
Orbital RMS differences



- The comparison between CPOD and DLR configurations led to a difference of **~0.28 cm 3D RMS**
- The comparison between CPOD and CNES configurations led to a difference of **~1 cm 3D RMS**
- The comparison between DLR and CNES configurations led to a difference of **~0.91 cm 3D RMS**
- The comparison between DLR and DLR* configurations led to a difference of **~1.93 cm 3D RMS**

- Maximum difference between GMV-DLR reprocessed orbits and DLR* solutions due to:
  - · Different software (NAPEOS vs. GHOST)
  - · DLR carries out ambiguity fixing

VALIDATION OF GNSS RESIDUALS



- CPOD and DLR configurations yield identical carrier phase and pseudo-range residuals.

- CNES configuration leads to slightly higher carrier phase residuals ~**1 mm**.

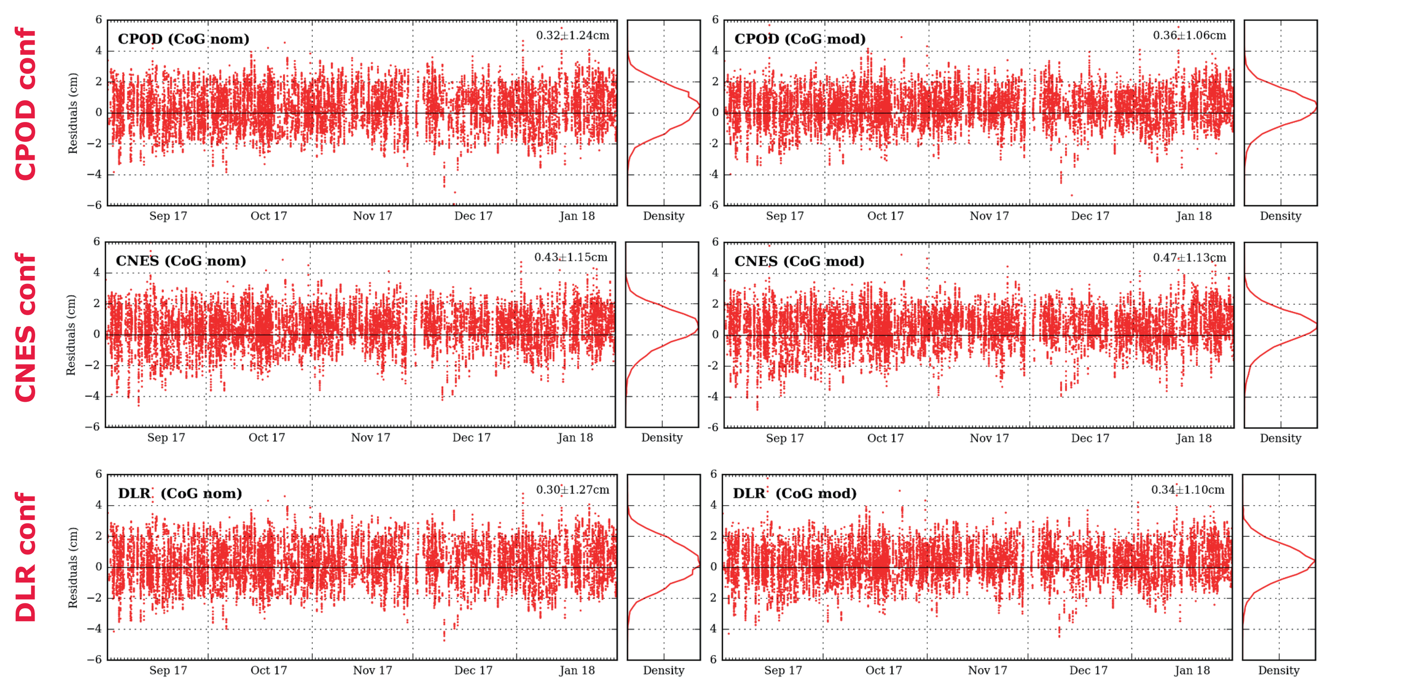
SLR VALIDATION

- Orbits are validated by analysing the residuals of SLR observations, fixing the orbits computed using the various configuration specified (see Table).

- The fit was performed considering two different configurations of the CoG with respect to the Retro Laser Reflector:

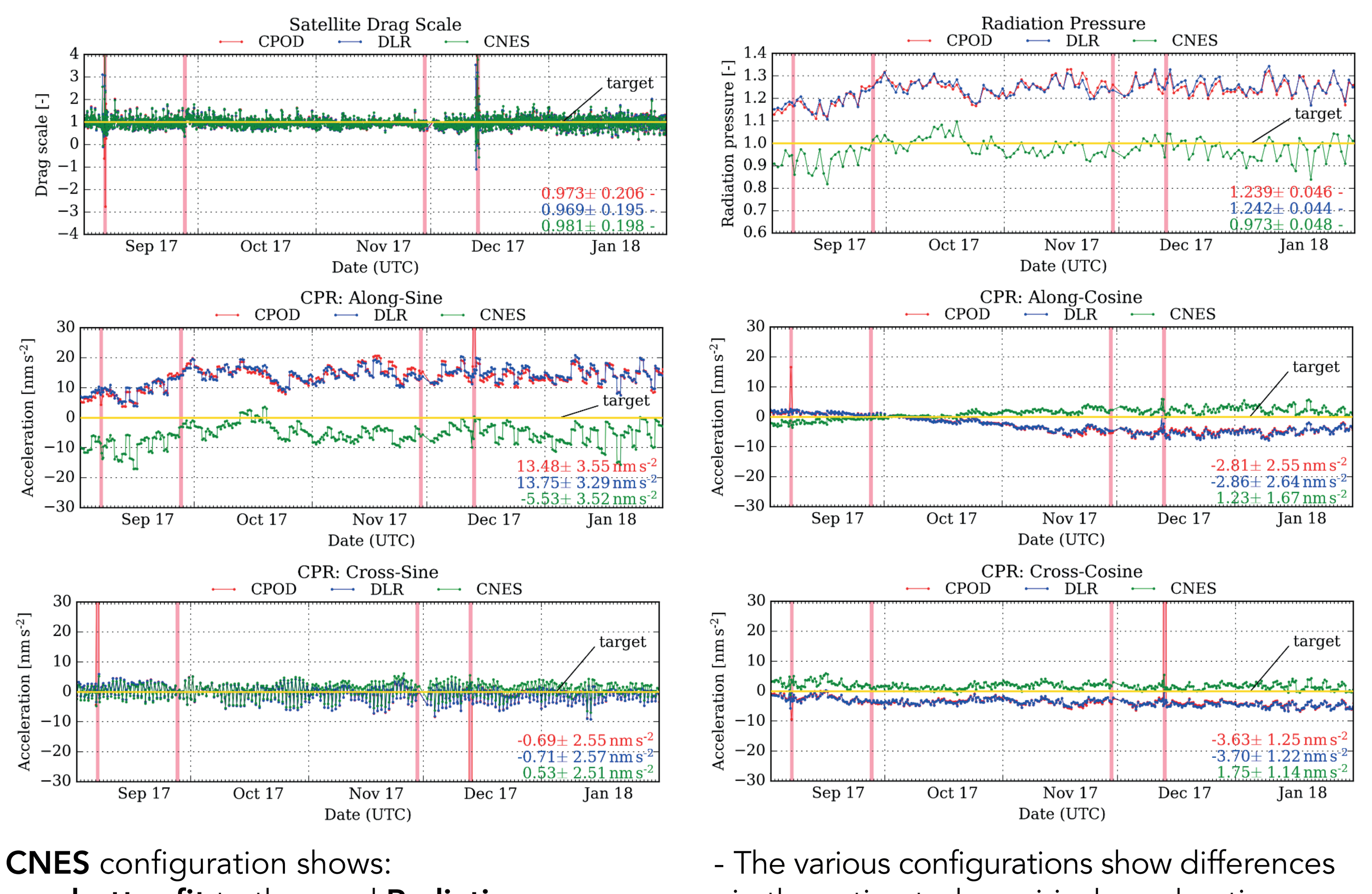
Case 1: Nominal CoG

Case 2: CoG Y-axis - 1cm (LRR Y-axis + 1cm)



- Very similar results for both settings and the three configurations:
  - · Mean residual increases by 0.4 mm
  - · Standard deviation decreases ~2 mm for CPOD and DLR conf. orbits

VALIDATION OF ESTIMATED PARAMETERS



- **CNES** configuration shows:
  - · **better fit** to the used **Radiation Pressure model**
  - · **smaller empirical accelerations** estimated during POD

- **CPOD** and **DLR** configurations lead to a similar estimated solar radiation pressure factor which is different than one.
  - · CPOD avg.: 1.239 -
  - · DLR avg.: 1.242 -

- The various configurations show differences in the estimated empirical accelerations. For CPOD/DLR vs. CNES:
  - · Bias of ~19 nms² in the along-sine component
  - · Mirrored along-cosine component
  - · Bias of ~5.5 nms² in the cross-cosine component
  - · Similar cross-sine component

CONCLUSIONS

- Three different set of orbits have been reprocessed offline by the **Copernicus POD Service** for the time period 1 September 2017 – 31 January 2018, using the nominal configuration (CPOD) as well as DLR and CNES proposed modifications. In all cases, the orbits were generated with NAPEOS.

- DLR configuration shows very similar results to the CPOD solution for all analyses performed.

- CNES configuration leads to contradictory conclusions, as it:
  - · shows a better fit to the **Radiation Pressure model** and **empirical accelerations**
  - · leads to slightly worse **GPS carrier** phase residuals and **SLR residuals**

- NAPEOS appears not to be sensitive enough to 1 cm shifts of the CoG-y, while PCO-z variations in the order of 1 cm do appear to yield slight variations (CNES configuration).

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