25 YEARS OF PROGRESS IN RADAR ALTIMETRY

COPERNICUS POD SERVICE
FIRST ORBIT DETERMINATION RESULTS FOR SENTINEL-3B

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ABSTRACT

Sentinel-3B, the twin satellite of Sentinel-3A, has been launched on 25 April 2018. During commissioning phase the radar altimeter satellite will fly in tandem (30 sec apart) with Sentinel-3A. This is mainly done for calibration and validation of the on-board instruments. During the commissioning phase of Sentinel-3B, the **Copernicus POD service** must verify and guarantee the stringent accuracy and timeliness requirements of the orbital and attitude products.

The 30 sec separation between S-3A and S-3B during the tandem phase gives an unique opportunities to perform ad-hoc performance comparisons between the accuracies, residuals and parameters estimated during the determination process for both Sentinel-3A and -3B. Being the latter a replica of the former, similarities between the results for both satellites are expected. The analyses carried out by the **Copernicus POD Service**, however, show some discrepancies which might be due to a slight misconfiguration of the satellite models involved.

In addition, during the tandem phase there has been several experiments to track GPS L2C signals with the redundant receiver, running in parallel to the nominal. The performance obtained will be presented in an ad-hoc presentation.

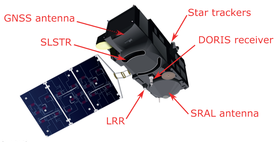
INTRODUCTION – SENTINEL-3 MISSION

- **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.

- Sentinel-3 carries, among others: a **Synthetic Aperture Radar Altimeter** (SRAL) to provide several ocean topography measurements. In order to obtain the best quality altimetry products, very stringent accuracy and timeliness requirements are posed for the Precise Orbit Determination (POD). For this purpose, Sentinel-3 is equipped with a dual-frequency GPS receiver, a DORIS receiver and a Laser Retro-Reflector (LRR).

- 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.

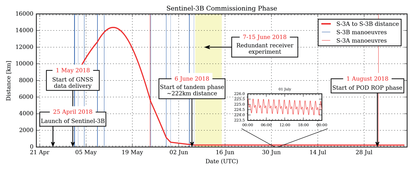
- **Sentinel-3B**, launched on April 25, 2018, is the second satellite of the Sentinel-3 mission and currently still in commissioning phase.



- Since June 6, 2018 the two Sentinel-3 satellites are flying 30 sec apart in a tandem to do several instrument calibrations.

- The commissioning phase of Sentinel-3B has been used to perform GPS L2C tracking tests with the redundant GPS receiver running in parallel with the main GPS receiver for this purpose.

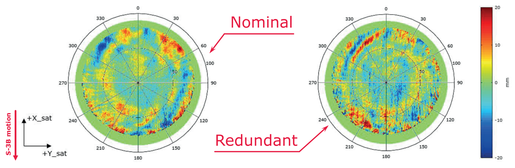
- This **poster** aims at presenting first orbit determination results from the commissioning phase of the satellite.



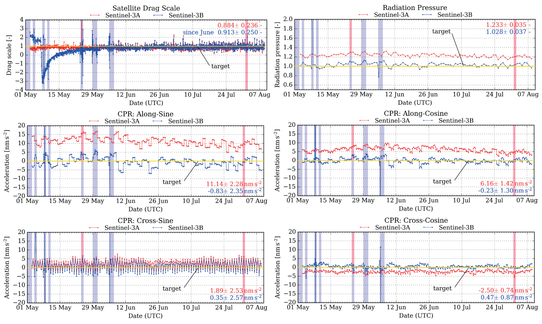
S-3B POD CONFIGURATION

Parameter	Elements	Nominal Configuration
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 (along/cross-track directions, 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 (pesudo-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
GPS ANTEX	Filename	sen08_2006.atx
	X_ant ; Y_ant ; Z_ant (mm)	0 ; 0 ; 68

- The configuration for **Sentinel-3B** is inherited from **Sentinel-3A**.
- **GPS ANTEX PCV maps** for both **nominal** and **redundant** receivers have been computed to minimize the phase delays of the GPS antenna on-board.



S-3B ESTIMATED PARAMETERS AGAINST S-3A



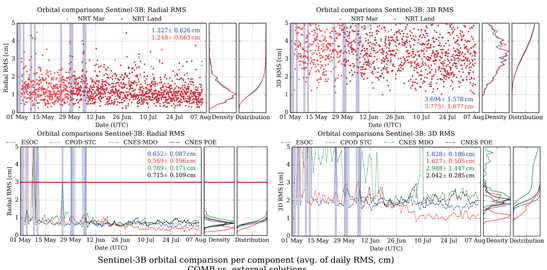
- **Sentinel-3B** shows a **better fit** to currently used models:
  - The satellite drag scale factor shows very similar values as for S-3A since the start of the tandem phase, very close to **one**.
  - The solar radiation pressure parameter is very close to one, maintaining a constant bias of ~0.2 [-] with respect to S-3A.
  - Empirical accelerations follow a similar oscillation patter as for S-3A, but with an average value of approximately **zero** (max of 0.83 nms^{-2}).

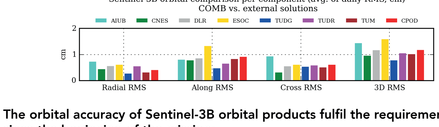
- Similarly to what happened with S-3A, the estimated S-3B drag scale factor evolves from negative values to the target value of one during the first month since launch due to out-gassing caused by the heating of the instruments.

- The comparison of estimated CPR brings a notorious difference between S-3B and S-3A, specially in the Along-Sine component pointing at an intrinsic slight misconfiguration on the S-3A modelling.

S-3B ORBITAL ACCURACY

The following plots show orbit comparisons; first row are wrt. CPOD MOE orbit, and the second raw are wrt. CPOD POE orbits





* Statistics for orbits spanning from June 7 to June 15

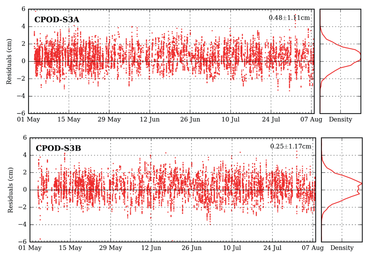
The orbital accuracy of Sentinel-3B orbital products fulfil the requirements since the beginning of the mission:

Timeliness	Requirement (1σ radial)	Average accuracy	Success ratio
Near Real Time (NRT)	10 cm	1.25±0.63 cm	**100%** (2664/2664)
Short Time Critical (STC)	4 cm	0.67±0.11 cm (vs ESOC) 0.77±0.15 cm (vs CNES)	**100%** (116/116)
Non Time Critical (NTC)	3 cm	0.54±0.07 cm (vs ESOC) 0.60±0.07cm (vs CNES)	**100%** (100/100)

* Statistics calculated with data from the launch of Sentinel-3B to 12/09/2018

S-3B SLR VALIDATION

Analysis of SLR residuals for S-3A and S-3B from 1 May to 7 August 2018:

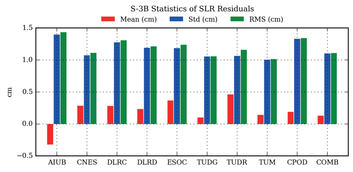


- **Average SLR residuals:**
  - **S-3A:** 0.48 cm
  - **S-3B:** **0.25 cm**

- **1-sigma SLR residuals:**
  - **S-3A:** 1.11 cm
  - **S-3B:** 1.17 cm

The **S-3B** orbital solutions show a **better fit to SLR** observations than in the case of S-3A. The used SLR measurements were provided by the following SLR stations: Wettzell, Hartebeesthoek, Yarragadee, Greenbelt, Haleakala, Graz, Potsdam, Herstmonceux and Matera.

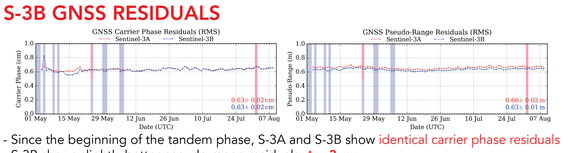
SLR residuals for each Quality Working Group centre from 8 June to 14 June 2018:



- **All centres** show average residuals **below 5mm**
  - **TU Delft, TUDG:** 1 mm
  - **TU Delft (redundant receiver), TUDR:** 4.6 mm

- Forthcoming extended results for RSR12 available in November 2018

S-3B GNSS RESIDUALS



- Since the beginning of the tandem phase, S-3A and S-3B show identical carrier phase residuals
- S-3B shows slightly better pseudo-range residuals: Δ ≈ **3 cm**

L2C SIGNAL EXPERIMENT

- **Experiment set-up and analysis of the results broadly presented in the presentation on Thursday 27 by Jaime Fernández:**
  14:50-15:05 | Sentinel-3B - GPS L2C tracking tests during commissioning phase

CONCLUSIONS

- Sentinel-3B was successfully launched on 25th April 2018 and is currently in commissioning phase. The **Copernicus POD Service** started the POD Routine Operational Phase on 1st August 2018, while orbital and attitude products were routinely delivered since the start of GNSS data delivery on 1st May 2018.

- The models and configurations employed for POD are identical to those for Sentinel-3A.

- All NRT, STC and NTC delivered orbital products comfortably fulfil the established requirements, excluding those impacted by data gaps and/or orbital manoeuvres.

- The presented results show systematic differences between Sentinel-3A and Sentinel-3B, even during the tandem phase. These extend to differences in:
  - estimated **radiation pressure** parameters and **empirical accelerations**
  - **GPS pseudo-range** residuals and **SLR fit** residuals

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