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SENTINEL-3 PRECISE ORBIT DETERMINATION AT THE COPERNICUS POD SERVICE

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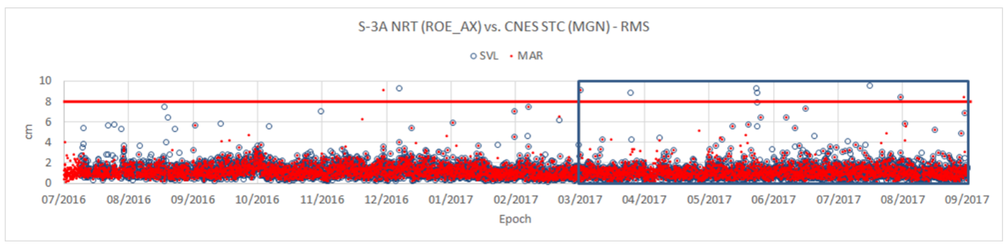
INTRODUCTION – POD FOR SENTINEL-3

- **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**, part of the Copernicus PDGS, 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 processor) deployed at the Marine Centre (@EUMETSAT) and Core Ground Station (@Svalbard Acquisition Station). The CPOD Service is supported by the **POD Quality Working Group** (QWG), comprised of several institutions across Europe, who routinely provide independent orbit solutions for accuracy assessment and contribute with different lines of research in orbit modelling improvement.

- This **poster** aims at presenting the quality control of official POD Products generated by the CPOD Service since S-3A launch, together with new developments including preliminary results of DORIS RINEX processing and the implemented SLR validation strategy.

S-3A POD QUALITY CONTROL – NRT

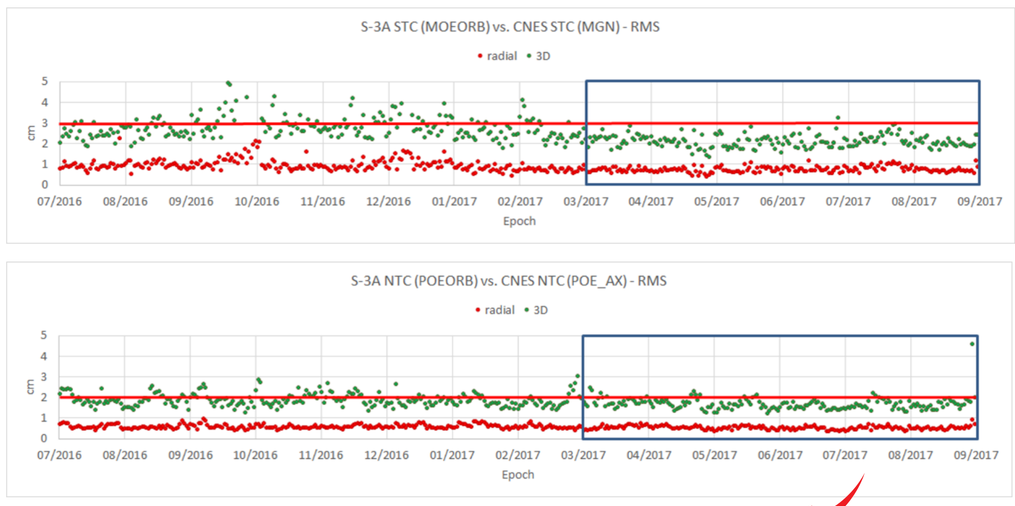


Statistics between 03/2017 and 09/2017

Solution*	RMS ave. (StDev)** [cm]	Req. % < 10 cm (Target % < 8 cm)	Timeliness ave. (StDev) [min]	Req. % < 30 min
Core Ground Station	1.2 (1.1)	99.45 (99.28) %	12.6 (2.3)	99.80 %
Marine Centre	1.2 (1.0)	99.51 (99.41) %	13.5 (2.2)	99.93 %

*Solutions generated by S3POD IPF, deployed at CGS (@ Svalbard Acquisition Station) and MAR (@EUMETSAT)
**excluding outliers, mainly due to long out-of-plane manoeuvres and missing recent GPS Orbits & Clocks

S-3A POD QUALITY CONTROL – STC & NTC



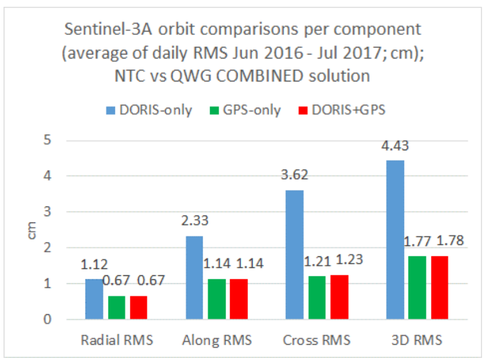
Statistics between 03/2017 and 09/2017

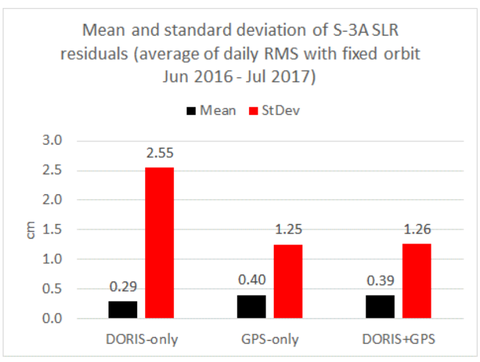
Solution	Radial RMS ave. (StDev)* [cm]	Req. % < 4/3 cm (Target % < 3/2 cm)	3D RMS ave. (StDev)* [cm]
MOEORB	0.71 (0.14)	100 (100) %	2.10 (0.33)
POEORB	0.50 (0.09)	100 (100) %	1.68 (0.34)

DORIS RINEX PRELIMINARY RESULTS

PROCESSING SETUP	
Software	NAPEOS
DORIS data	RINEX 3.0 phase measurements – processed as Phase Differences (10s baseline)
DORIS receiver clock model	Estimated from a 4th order polynomial fit to F observation type in RINEX
Station coordinates	DPOD2014 + Post-Seismic Deformation (ITRF14) file
GPS satellites orbits & clocks	Fixed; IGS finals (clocks every 30s)
Gravity Field	EIGEN.GRGS.RL03.v2.coef with mean slope extrapolation
Tropospheric Model	Saastamoinen with GPT, GMF and estimated parameters
Attitude Model	Quaternions determined on-board
Data weighting	GPS phase: **10 mm**; GPS pseudorange: **0.8 m**; DORIS phase difference: **4 mm**
Elevation cut-off angle	10º
Estimated orbit parameters	10 Drag Coefficients per day 2 CPRs - Empirical Acceleration Parameters (in along/cross directions with sine/cosine components) per day 1 Solar Radiation Pressure Coefficient
Estimated GPS parameters	1 GPS phase ambiguity per GPS satellite pass 1 Receiver clock bias per epoch
Estimated DORIS station parameters	1 Station Delay (Range-Rate Bias) per station pass 1 Atmospheric Zenith Delay per station pass
Arc Length	3 days

DORIS RINEX PRELIMINARY RESULTS





Solution	#of accepted / rejected obs. in 72h arc	DORIS phase diff. res. [mm]	GPS phase res. [mm]	GPS pseudo-range res. [m]
DORIS-only	~29,500 / ~1,100	3.97	-	-
GPS-only	~190,800 / ~2,200	-	6.34	0.64
DORIS+GPS	GPS: ~191,200 / ~1,800 DORIS: 30,300 / ~300	4.37	6.36	0.66

- **Consistent** results with respect to GPS when incorporating DORIS into orbit determination.

- Validation against **IGS-like combined solution** (generated from POD QWG orbits) and using **SLR residuals** show that GPS-only and GPS+DORIS solutions are very much alike.

- **DORIS-only** orbits are of excellent quality as well, showing radial RMS close to 1 cm

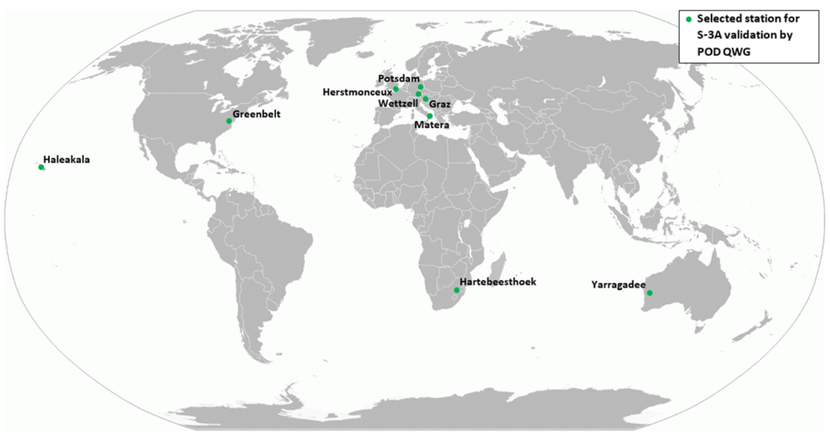
SLR VALIDATION – POD QWG RESULTS

- **Satellite Laser Ranging (SLR)** measurements provided by ILRS are used as independent source of orbit accuracy validation.

- The validation strategy in place consists of **fixing** the orbits obtained from other techniques (such as GPS and DORIS) and computing the SLR residuals with respect to the orbit. Thus, the SLR measurements are not incorporated into the orbit determination process.

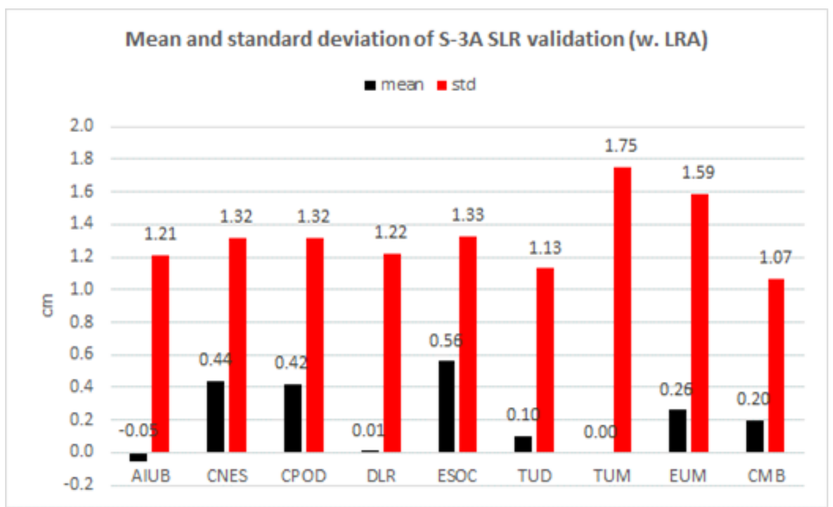
- In order to harmonise the results, a list of **core ILRS stations** has been selected by the POD QWG based on residuals analysis from Lageos-2, Jason-2 and Sentinel-3A, in order to exclude satellite-specific issues. Moreover, only stations not impacted by the PSD (Post Seismic Deformation) have been selected. The selected list includes **9 stations** (shown below), for which mean and standard deviation of SLR residuals is presented.

ILRS Core-Network Stations selected for S-3A validation



SLR VALIDATION – POD QWG RESULTS

- **SLR residuals** computed for all members of POD QWG (AIUB, CNES, CPOD, DLR, ESOC, TU Delft, TU Munich and EUMETSAT), as well as for an IGS-like combined solution, for a timespan between 1st April 2016 – 31st May 2017.



Results from this analysis prove that the orbits are of **excellent quality** (with a standard deviation below 1.5 cm for all centres). A bias of ~ 0.5 cm is observed for dynamic solutions (mainly, CNES, CPOD, ESOC and EUMETSAT), which is not present for the rest of orbits based on a more kinematic approach. Further investigations to understand the source of the bias are on-going in the POD QWG.

CONCLUSIONS

Sentinel-3 mission poses stringent requirements for the **POD** both in terms of accuracy and timeliness in order to fully exploit the quality of its scientific products. These **requirements are routinely fulfilled** by the CPOD service, which has developed and is responsible for the operation of a robust system. Independent validation of the POD products is possible thanks to the support provided by the **POD QWG** members and the **ILRS** community, proving that the orbits and auxiliary data meets the expected accuracy.

In addition, the CPOD Service is responsible for the **evolutions** of the system, which is continuously under improvement by carrying out different analysis with the aim of rising the performance and acquiring new knowledge needed by the future coming challenges. In this poster, preliminary results of **DORIS RINEX** processing have been presented, opening the possibility to include a new operational product in the future.

Acknowledgements:

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