COPERNICUS POD SERVICE

STATUS OF COPERNICUS SENTINEL SATELLITE ORBIT DETERMINATION

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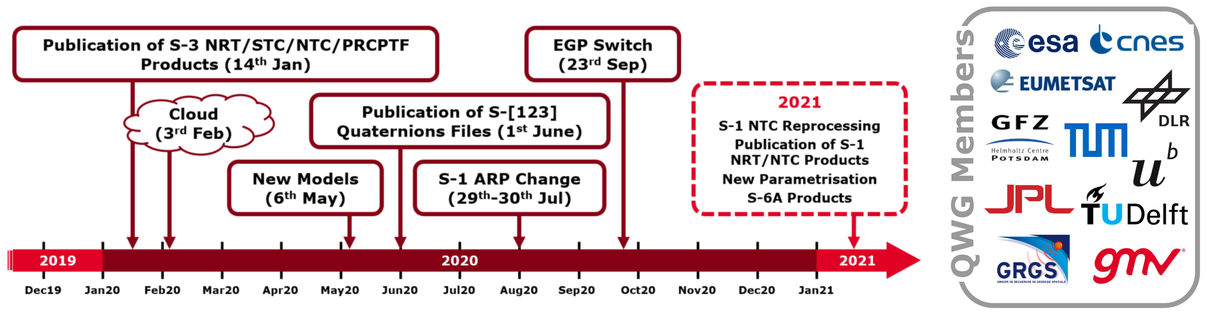
Please also consult: Peter, H. et al. (2020), **Updates in the Non-Gravitational Force Modelling and Orbit Parametrization of the Copernicus Sentinel-1, -2, -3 satellites**, POSTER PSD.1-0026-21

Abstract

The Copernicus Precise Orbit Determination (CPOD) Service, as part of the ground segment of the Copernicus Sentinel-[123] missions, delivers orbital products and auxiliary data files for their use in the corresponding Payload Data Ground Segment (PDGS) processing chains.
The processing setup of the CPOD Service has been updated to state-of-the-art background models (geopotential, ocean tides and atmospheric gravity), and the use of single-receiver ambiguity fixing by means of CODE (Center for Orbit Determination in Europe) GPS orbits, clocks and biases products in spring 2020. Further investigations on an update of the orbit parametrisation have led to an optimised setup, which performance will be presented through this poster. Thus, orbit comparisons of the precise orbital products from the three missions against a combined orbit product (COMB) will be analysed. This COMB solution has been calculated using the orbit solutions provided by the members of the Copernicus POD Quality Working Group (QWG). In addition, this poster will also address the orbit accuracy validation based on Satellite Laser Ranging (SLR) measurements (only possible for Sentinel-3 satellites). Finally, geographically related differences and Fourier analysis of orbit differences are also added to the validation scheme.

1. CPOD SERVICE SUMMARY

During the last months, the Copernicus Precise Orbit Determination (CPOD) Service has carried out different activities (see figure below) not only to continue improving the accuracy of the generated products but also to evolve the system to emerging technologies. One key activity finally concluded by the CPOD Service at the beginning of 2020 has been the migration of the CPOD system to a cloud environment (see more details in the following section). On 23rd September, new main and backup External GNSS Providers (EGPs) came in place with the renewal of the service contract, bringing new challenges within the multi-GNSS paradigm.
More information about the status of the service and relevant POD data of the Sentinels missions can be found in the **Sentinels online webpage**. From all these data, the CPOD Service is in charge of uploading POD products to the user community on a daily basis. Most of the products are publicly available at the **ESA Copernicus Open Access Hub**. In the upcoming days, Sentinel-1 orbit products will also be published, the generation of which will take into account the recent change on the Antenna Reference Point (ARP) of both satellites [1].

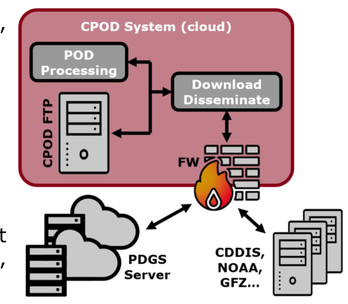


2. CLOUD INFRASTRUCTURE

The CPOD Service has been migrated from GMV premises to a cloud infrastructure, taking over ground operations on 3rd February 2020. Some of the benefits are:

- **Hardware scalability:** allocation of extra resources based on load demand.
- **No hardware maintenance:** this is a responsibility of the cloud provider.
- **Enhanced robustness:** out-of-the-box redundancy of infrastructure elements.
- **Improved interface:** inwards/outwards bandwidth increased (x10).
- **New technologies:** the cloud opens the door to cutting-edge technologies.

The transition from ground to cloud infrastructure has been smooth and transparent for the final users. The cloud system has proved to maintain the service performance, being reliable and highly-accessible during this first 10 months of operations.



3. MODEL UPDATES & NEW PARAMETRISATION

On the continuous improvement of the POD products, the CPOD Service has recently performed an important modelling update, which details can be found in the left table below. As a result of the outcome obtained by this new modelling, the CPOD Service has also analysed the use of a new parametrisation on the POD products (see right table below). This new parametrisation is not operational yet but it is intended to be soon on next year. The performance of both updates is shown in the following sections (further details can be found in the **Regular Service Review** (RSR) documents periodically uploaded on the Sentinels online webpage).

Model Updates		
Model/Parameter	Old Configuration	New Configuration (6th May)
Gravity field (static)	EIGEN.GRGS.RL03.v2 (120x120)	EIGEN.GRGS.RL04 TVG (120x120)
Gravity field (time varying)	Drift/annual/semi-annual piece wise linear terms up to degree/order 50	Drift/annual/semi-annual piece wise linear terms up to degree/order 90
Ocean tides	EOT11a (30x30, 99 tidal constituents)	FES2014 (100x100, 142 tidal constituents)
Atmospheric gravity	ATM_GEOSFPIT (64x64)	GFZ AOD L1B RL06 (100x100)
Atmospheric tides	Ray-Ponte 2003	GFZ AOD L1B RL06 (100x100)
Atmospheric density	msise90	msise00
Receiver ambiguities	Estimated (float)	Estimated (fixed)
GPS orbits	Fixed (IGS finals)	Fixed (CODE finals)
GPS clocks	Fixed (IGS finals)	Fixed (CODE finals, 30 s)
GPS satellite biases	-	CODE finals

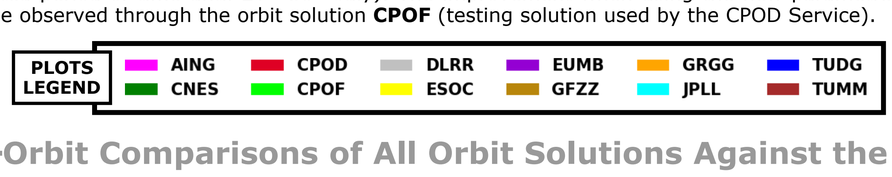
New Parametrisation		
Parameter	Operational Configuration	New Configuration (2021)
Radiation pressure coefficient	Estimated 1 coefficient per arc (loosely constrained to 1.0)	Fixed 1 coefficient per arc (S-[12] to 1.0, S-3A to 0.97, and S-3B to 0.96)
Drag coefficients	Estimated 10 coefficients per day (loosely constrained to 1.0). Estimated 15 coefficients for 32 h	Estimated 1 coefficient per arc (constrained with 0.3)
1/rev empirical	Estimated 3 sets per arc: Along: sine + cosine Cross: sine + cosine	Estimated 16 sets per arc: Along: constant, sine + cosine Cross: constant, sine + cosine (constrained with 10e-12 km/s², 10e-11 km/s²)
GPS clocks	Fixed (CODE finals, 30 s)	Fixed (CODE finals, 5 s)

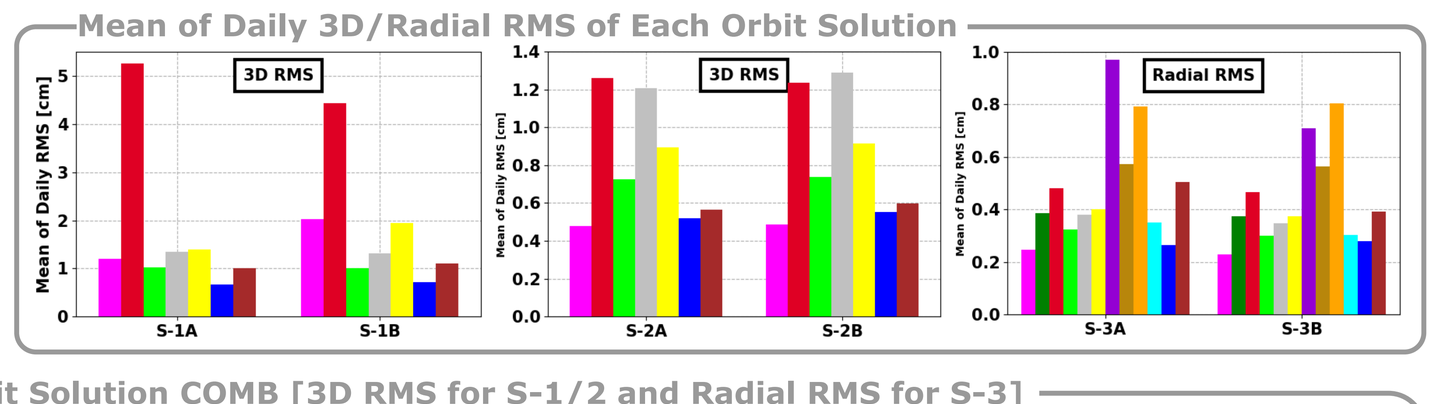
Changes performed on orbit solutions CPOD and CPOF

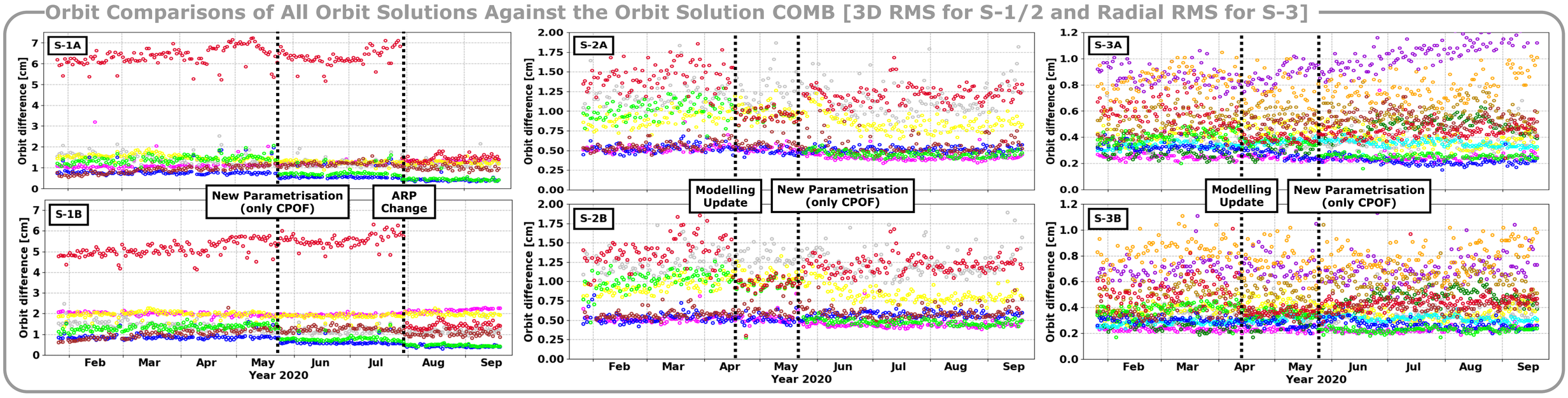
Changes performed on orbit solution CPOF (since 24th May)

4. CPOD SERVICE PRODUCTS PERFORMANCE

The endorsement of the **Copernicus POD Quality Working Group** (QWG) is essential to fully validate the modelling updates proposed for the operational CPOD Service POD products. The figures below show the orbit comparisons (3D RMS for S-1/2 and radial RMS for S-3) between the different orbit solutions provided by all centres of the QWG against a combined orbit solution (COMB) generated from the merge of all solutions with proper weights and following an "IGS-like" approach. On the right, a statistical summary of the previous orbit comparisons can be found .
From these figures, it can be seen the accuracy improvement of the operational CPOD Service orbits labelled as **CPOD** after having performed the modelling update on 6th May (on S-1 orbits, this improvement cannot be clearly seen since a different ARP configuration has been used on the reported period of time until 29th-30th July). The improvement when using the new parametrisation can be observed through the orbit solution **CPOF** (testing solution used by the CPOD Service).

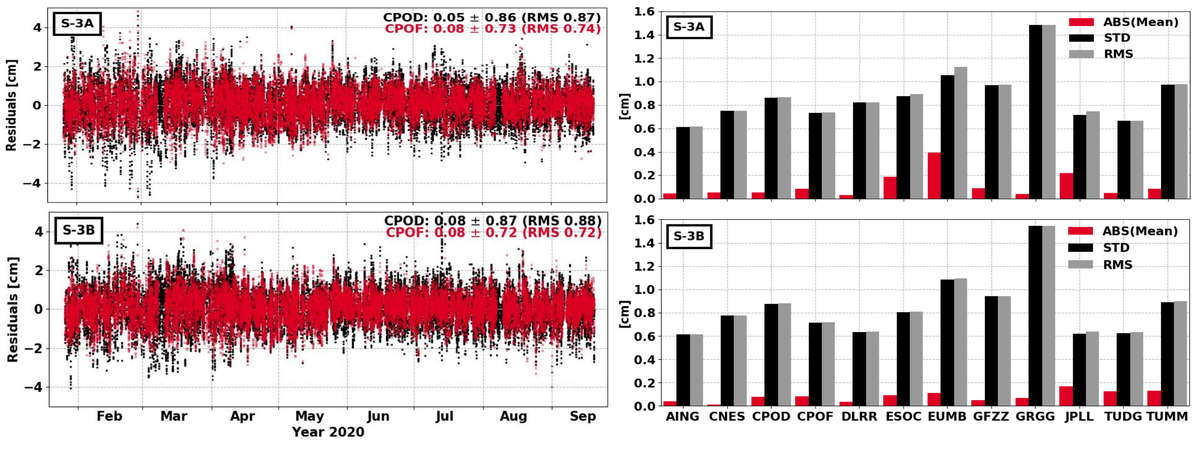






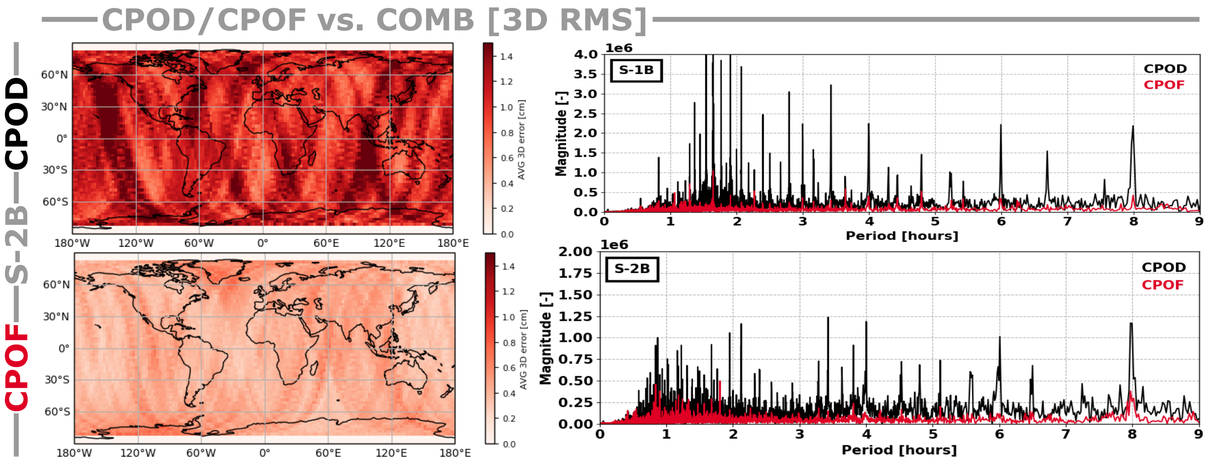
5. SENTINEL-3 SLR VALIDATION

The **ILRS community** provides an independent set of observations that are also used by the CPOD Service in order to validate the generated orbits. However, only the orbits of S-3 satellites can be validated by this means since a Laser Retro Reflector (LRR) is not available on S-1 and S-2 satellites. From the figures below, it can be seen that (a) the orbit solution CPOF (including both updates) obtains better statistical results than the orbit solution CPOD (only modelling updates), and (b) the orbit solution CPOF is one of the best QWG solutions fitting laser observations.



6. GEOGRAPHICAL AND SPECTRAL ANALYSES

The geographical and spectral analyses also provide confirmation that the evolutions performed on the CPOD Service products yield better solutions. On the left plots below, an example of geographical plots showing the daily mean of the 3D RMS of S-2B CPOD/CPOF orbit solutions is shown. On the right, it can be found the spectral analysis derived from the orbit comparison [3D RMS] between S-[12]B CPOD/CPOF orbit solutions against the COMB. On both analyses, it can be seen that better outcome is achieved by CPOF (smaller amplitude signals are obtained).



7. CONCLUSIONS & FUTURE WORK

Products Published on the ESA Copernicus Open Access Hub			
Product	S-1	S-2	S-3
Near-Real Time Orbits	2021	-	X
Short Time Critical Orbits	-	-	X
Non-Time Critical Orbits	2021	-	X
Precise Platform Files	-	-	X
RINEX L1B Files	X	X	X
Quaternions Files	X	X	X

The modelling update (already implemented) and the new parametrisation (to be operationally deployed in early 2021) have shown a significant improvement on the accuracy performance of the CPOD Service products. The SLR validation has also confirmed that the changes performed are in line with the laser observations outcome that the SLR stations retrieve from the tracking of Sentinel-3 satellites.
On the other hand, the ARP of Sentinel-1 satellites has been updated in order to fix a misconfiguration on their values [1]. This fact will lead to a Sentinel-1 reprocessing campaign in order to align all S-1 precise products provided by the CPOD Service to the new ARP configuration. These products will be published on the ESA Copernicus Open Access Hub once they are ready. This will increase the availability of POD products online (see table on the left for the complete list of available products).
Coming next year, the CPOD Service will be able to provide POD products for the new Sentinel-6A satellite successfully launched on 21st November 2020.

Acknowledgements

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REFS [1] Peter, H., Fernández, J., and Féménias, P., Copernicus Sentinel-1 satellites: sensitivity of antenna offset estimation to orbit and observation modelling, Advances in Geosciences (ADGEO), 50, 87-100, 2020, https://adgeo.copernicus.org/articles/50/87/2020/

Sentinels online webpage

ESA Copernicus Open Access Hub

gmv INNOVATING SOLUTIONS