PSD.1-0026-21

43rd COSPAR Scientific Assembly
28 January – 4 February 2021
PSD.1

Updates in the non-gravitational force modelling and orbit parametrization of the Copernicus Sentinel-1, -2, -3 satellites

Please also consult **Fernández M., Berzosa J., Fernández C. et al. (2020) Copernicus POD Service: Status of Copernicus Sentinel satellite orbit determination,** Poster PSD.1-0027-21

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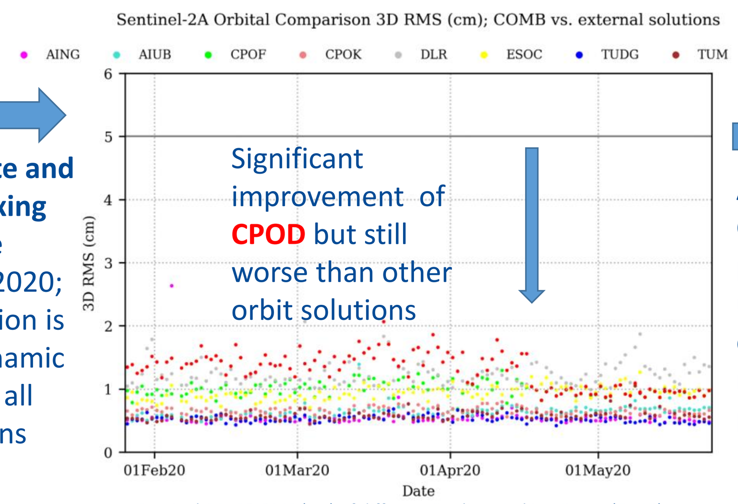
Introduction / Abstract

The Copernicus POD (Precise Orbit Determination) Service is responsible for the generation of precise orbital products of the Copernicus Sentinel-1, -2, and -3 missions.
The six satellites of the three Copernicus missions are flying in different altitudes and different orbits. To the largest extent possible, the orbit parametrization is the same for all six satellites.
Following a large background model update in spring 2020 the orbit parametrization is reviewed in detail to improve the orbit solutions even more.
An offline reprocessing based on the current processing setup has been done to compute daily estimates of the solar radiation pressure (SRP) coefficient for all satellites. Using these mean values of the SRP coefficients and refining the number of empirical accelerations improves the orbits significantly. The impact of the updated modelling on the orbit results and on the orbit quality is presented for all six satellites.

CPOD Service Sentinel POD settings

- NAPEOS (NAVigation Package for Earth Orbiting Satellites)
- IERS2010 conventions
- GPS: **CODE** final orbits, clocks (5 s), and biases; igs14.atx
- Sentinel: 10 s GPS data, 1° x 1° PCVs, **ambiguity-fixed** solution
- 32 h arc; S3: 19:00 (day-1) – 03:00 (day+1); S1&S2: 20:00 (day-1) – 04:00 (day+1)
- **EIGEN.GRGS.RL04** gravity field (120 x 120), time-variable coefficients (50 x 50)
- **FES2014 ocean tides (100 x 100)**
- **GFZ AOD L1B, atmosphere tides from GFZ AOD product**
- Satellite macro model for non-gravitational force modelling
- Atmosphere model **MSISE00 + HWM14**, 15 drag coefficients per arc
- Earth albedo and IR radiation
- One solar radiation pressure (SRP) coefficient per arc

- Empirical CPR (cycle-per-revolution) parameters: three sets/arc
  - along-track sine + cosine, cross-track sine + cosine



Sentinel-2A: 3D RMS (cm) of different Quality Working Group (QWG) orbit solutions w.r.t. combined QWG orbit solution for Regular Service Review (RSR) #17 period (Feb – May 2020) [2]

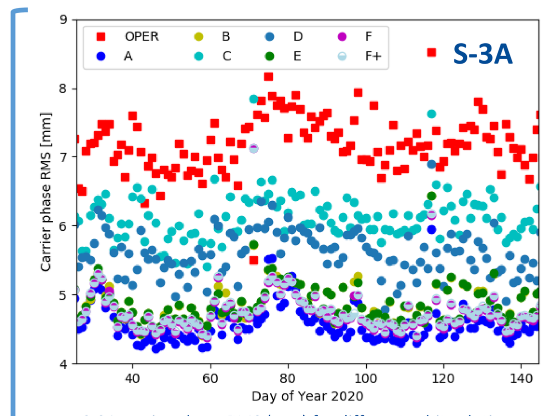
Model update and ambiguity-fixing applied since mid of April 2020; parametrization is still most dynamic compared to all other solutions

Analysis of CPOD orbit parametrization update; less dynamic and more empirical parameters

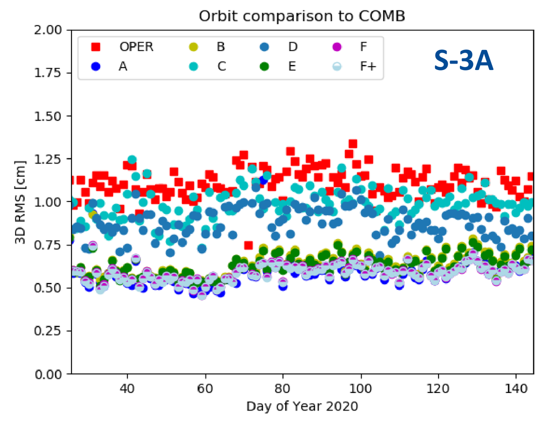
	Drag scale factor	SRP scale factor	1/rev parameter
CPOD OPER	15 / arc (constraint: 1.0)	1 / arc	3 / arc alo: sin+cos (constraint: $1\cdot10^{-5}$ km/s^2) cro: sin+cos ($1\cdot10^{-5}$ km/s^2)
A	1 / arc (constraint: 1.0)	Fixed to 1.0	64 / arc alo: const ($1\cdot10^{-9}$ km/s^2) cro: const ($1\cdot10^{-9}$ km/s^2)
B	1 / arc (constraint: 1.0)	Fixed to 1.0	15 / arc alo: const,sin+cos ($1\cdot10^{-9}$ km/s^2) cro: const,sin+cos ($1\cdot10^{-9}$ km/s^2)
C	1 / arc (constraint: 1.0)	Fixed to 1.0	10 / arc alo: const,sin+cos ($1\cdot10^{-9}$ km/s^2) cro: const,sin+cos ($1\cdot10^{-9}$ km/s^2)
D	1 / arc (constraint: 1.0)	Fixed to 1.0	12 / arc alo: const,sin+cos ($1\cdot10^{-11}$ km/s^2) cro: const,sin+cos ($1\cdot10^{-11}$ km/s^2)
E	1 / arc (constraint: 0.3)	Fixed to 1.0	15 / arc alo: const,sin+cos ($1\cdot10^{-12}$ km/s^2, $1\cdot10^{-11}$ km/s^2) cro: const,sin+cos ($1\cdot10^{-12}$ km/s^2, $1\cdot10^{-11}$ km/s^2)
F F+: S3A&S3B	1 / arc (constraint: 0.3)	Fixed to 1.0 F+ S3A:0.97 F+ S3B:0.96	16 / arc alo: const,sin+cos ($1\cdot10^{-12}$ km/s^2, $1\cdot10^{-11}$ km/s^2) cro: const,sin+cos ($1\cdot10^{-12}$ km/s^2, $1\cdot10^{-11}$ km/s^2)

Favourite solution

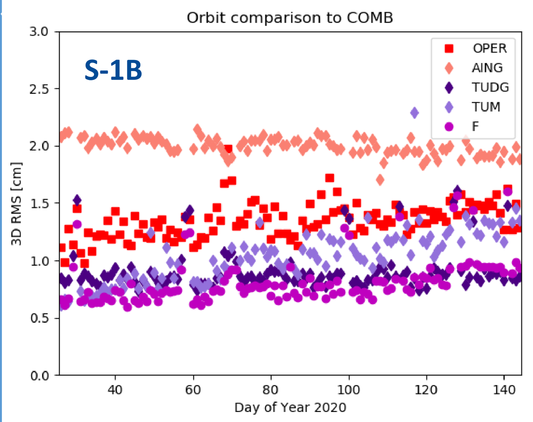
List of different test orbit solutions to analyse the performance of a more reduced-dynamic orbit parametrization for the CPOD solution.



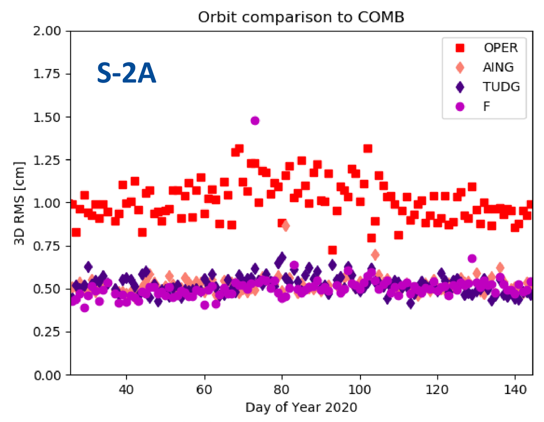
S-3A carrier phase RMS (mm) for different orbit solutions



S-3A 3D RMS (cm) of different orbit solutions w.r.t. combined QWG orbit solution (from [3])



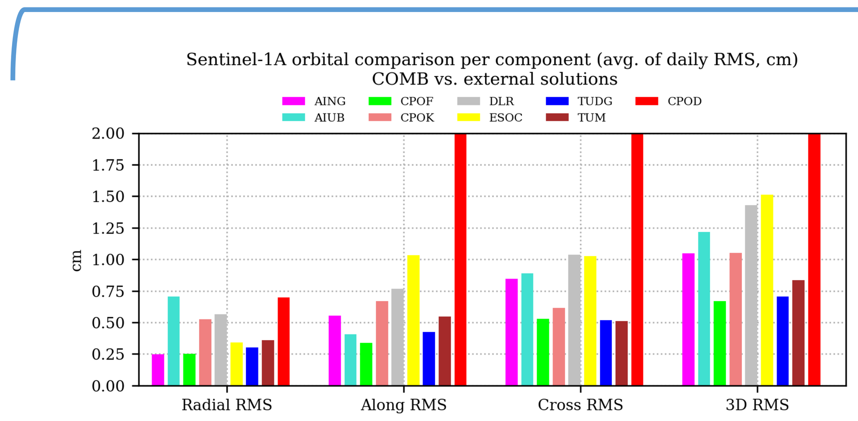
S-1B 3D RMS (cm) of different orbit solutions w.r.t. combined QWG orbit solution

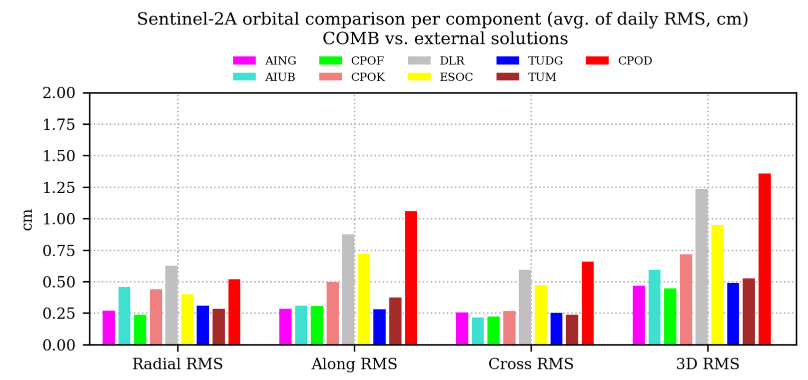


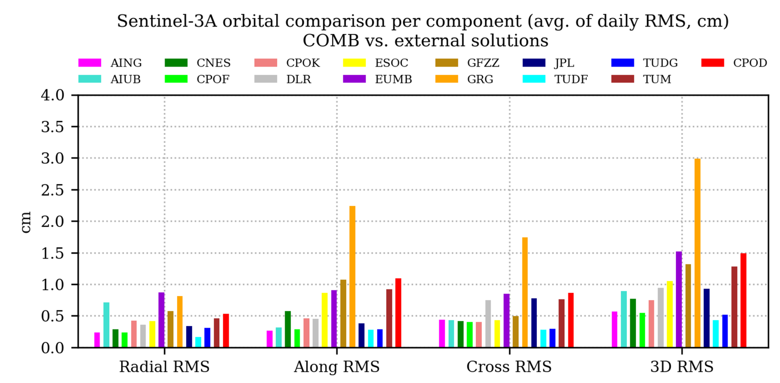
S-2A 3D RMS (cm) of different orbit solutions w.r.t. combined QWG orbit solution

All test solutions for S-3A show lower carrier phase RMS than the CPOD OPER solution (top left) and the differences from all test solutions to the combined QWG orbit are smaller than for the CPOD OPER solution (top right). The favourite solution F is also preferable to the CPOD OPER solution for the other satellites (bottom left and right).

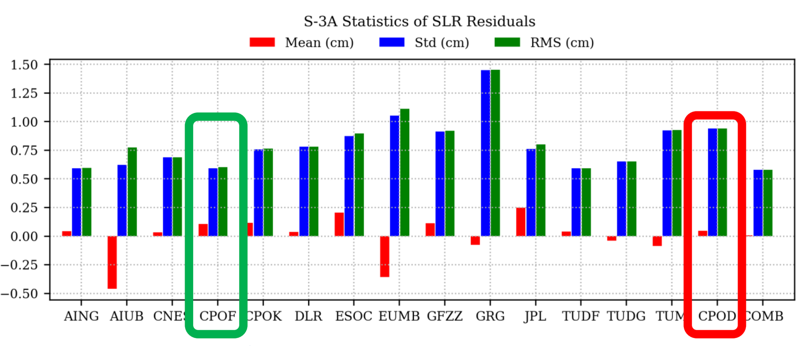
- The current CPOD orbit parametrization is based on state-of-the-art background models.
- The comparison of different orbit solutions to combined QWG orbit solution reveals, however, that a more reduced-dynamic parametrization could be feasible.
- More empirical parameters may catch up remaining model deficiencies.
- Empirical parameters in radial direction are avoided to stick to the dynamic models as much as possible in this direction => very important for S-3 altimeter mission
- Solution F/F+ is the favourite solution for a new CPOD orbit parametrization
- Generation of QWG combined orbit solution for RSR#17 (Feb-May 2020) is repeated with including **CPOF** based on parametrization of solution F/F+







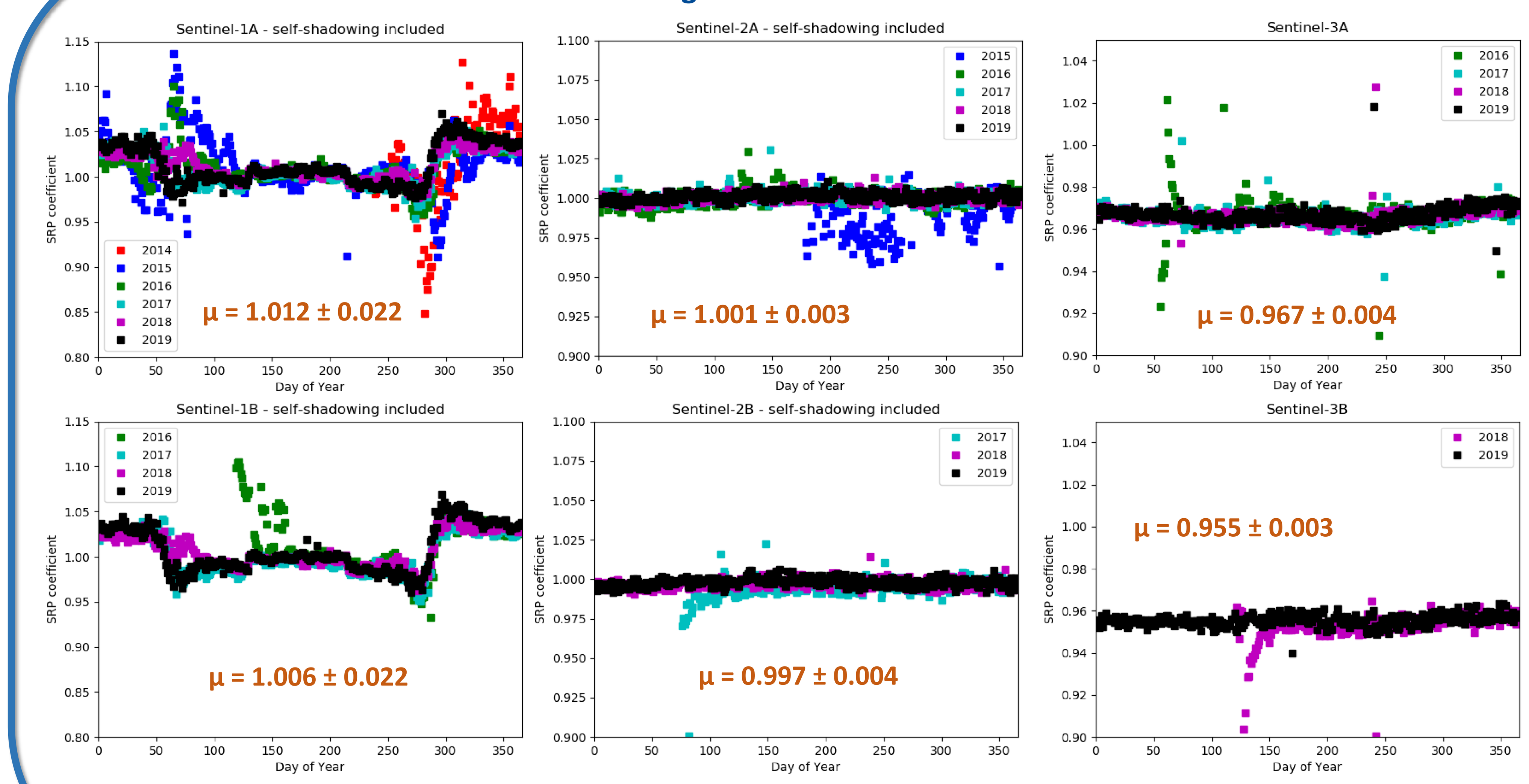
The new **CPOF** solution shows much better performance than the current operational **CPOD** solution for all satellites. **CPOF** is now one of the best orbit solutions compared to the combined QWG orbit solution. The external validation with Satellite Laser Ranging (SLR) measurements for S-3 also show the improvement of the **CPOF** solution compared to the **CPOD** solution.



S-3A	Mean (cm)	Standard dev (cm)
CPOD*	0.05	0.94
CPOF	0.10	0.59
S-3B		
CPOD*	0.08	0.94
CPOF	0.08	0.59

* Note: CPOD was partly still based on old background models and carrier phase ambiguities were not yet fixed

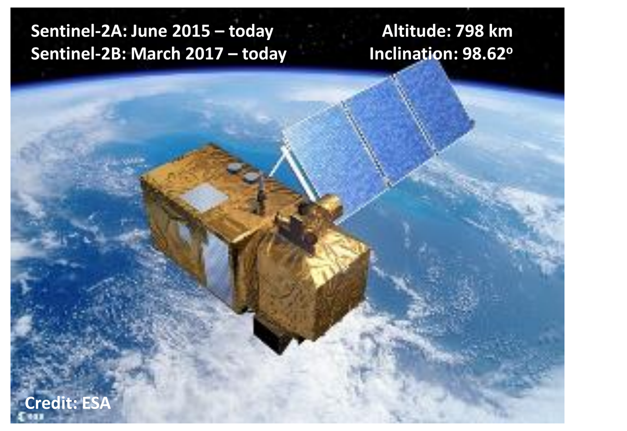
Long-term SRP estimation



Results for long-term SRP estimates for all six satellites, published in [1]. Except for Sentinel-1 the SRP coefficients are very stable over the year. This gives good confidence in the satellite macro models used for Sentinel-2 and -3.

Copernicus Sentinel-1

Copernicus Sentinel-2



Copernicus Sentinel-3

Copernicus POD Quality Working Group

The Copernicus POD Service is supported by the Copernicus POD Quality Working Group (QWG) which is built by POD experts from the following institutions:

- Astronomical Institute, University of Bern, Switzerland
- Deutsches Zentrum für Luft- und Raumfahrt, Oberpfaffenhofen, Germany
- European Space Operations Centre, Darmstadt, Germany
- Delft University of Technology, Delft, The Netherlands
- Technische Universität München, Munich, Germany

Only for S-3:

- Helmholtz Zentrum Potsdam – Deutsches GeoForschungsZentrum, Potsdam/Oberpfaffenhofen, Germany
- CLS (Collecte Localisation Satellite) / GRGS (Groupe de Recherche de Geodèsie Spatiales), Toulouse, France
- CNES (Centre Nationale d'Etudes Spatiales), Toulouse, France
- Eumetsat (European Organisation for the Exploitation of Meteorological Satellites), Darmstadt, Germany
- Jet Propulsion Laboratory (JPL), NASA, Pasadena, CA, US

The QWG institutions provide independent Sentinel orbit solutions for validation. Different software packages and different orbit parametrization are used from the QWG.

Summary and conclusion

The Copernicus POD Service provides precise orbital products for the first three Copernicus Sentinel missions. Although these Earth observation missions have different characteristics the orbit parametrization is the same for all satellites. Recent background model update significantly improved the orbit accuracy.
The goal of this study was to review and refine the orbit parametrization to even further improve the orbit determination results. Fixing the SRP coefficients, reducing the number of atmospheric scaling factors but increasing the number of empirical parameters led to an improved parameter setup for all six satellites.
As soon as the new parametrization is approved by the Copernicus POD QWG it will be applied in the operational processing setups of the non-time critical orbit determination schemes of the satellite missions.

References
[1] Peter, H., Berzosa, J., Fernández, J., and Féménias, P.: Long-term evaluation of estimated solar radiation pressure coefficients from Copernicus Sentinel-1, -2, -3 satellites, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-5288, https://doi.org/10.5194/egusphere-egu2020-5288, 2020
[2] Copernicus POD Regular Service Review Feb – May 2020, GMV-GMESPOD-RSR-0017_v1.1
[3] Peter H., Berzosa J., Fernández M. et al. (2020) Copernicus POD Service – Evolutions in Sentinel-3 Orbit Determination, presented at virtual OSTST2020, October 19-23, 2020 https://meetings.aviso.altimetry.fr/fileadmin/user_upload/tx_ausyclsseminar/files/OSTST20_CPODS3OrbitEvolution_HPeter_v2.pdf

Poster compiled by H. Peter, November 2020
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Acknowledgements: The Copernicus POD Service is financed under ESA contract no. 4000132155/20/I-BG, which is gratefully acknowledged. The work performed in the frame of this contract is carried out with funding by the European Union. The views expressed herein can in no way be taken to reflect the official opinion of either the European Union or the European Space Agency.