Copernicus Sentinel-1 Orbits – Results of an Offline Reprocessing

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See also: Peter et al. **Copernicus POD Service: Reprocessing of Sentinel-1, -2, and -3 Orbits**
Fernández et al. **Single-receiver Ambiguity Resolution for Copernicus Sentinel Satellites at the Copernicus POD Service**

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Introduction

The Copernicus POD (Precise Orbit Determination) Service is among others responsible to deliver orbital and auxiliary data files to the PDGS of the Sentinel-1 mission. The orbits are needed to provide highest level (In)SAR products of the mission.

To guarantee this highest level a consistent time series of the orbits is essential. The operational orbit processing at the Copernicus POD Service is done as consistent as possible over time but nonetheless several model updates and improvements have been made during the years. This is in particular true for the orbit time series of Sentinel-1A being the oldest satellite (April 2014) in the Copernicus Sentinel satellite series.

An offline reprocessing has been performed to have consistent time series available for all Sentinel satellites.

A major change for Sentinel-1 is the correction of wrongly used coordinates of the antenna reference points for the GPS antennas of both satellites (not yet corrected for the operational products). This implies a change of the absolute orbit positions of several cm. Additionally, analyses of differences between the results from both satellites revealed a possible update of the Phase Center Offset (PCO) coordinates of the satellites.

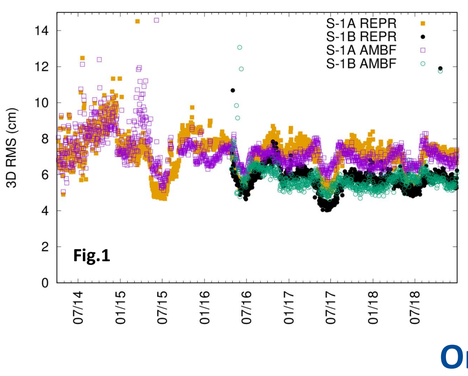
Sentinel-1A and -1B orbit results from this offline reprocessing are presented in detail considering the large impact of the antenna reference point updates. The improvements gained by the consistent reprocessing are presented among others in terms of orbit comparisons, orbit overlap analysis and analysis of the estimated orbit parameters.

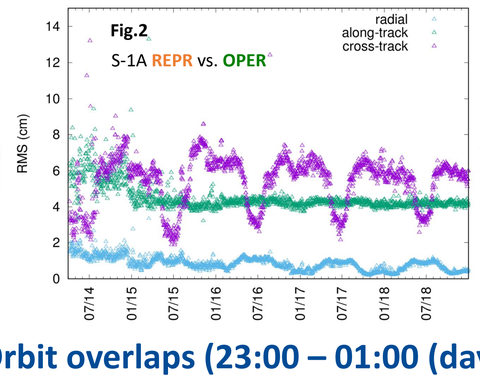
Available orbit solutions

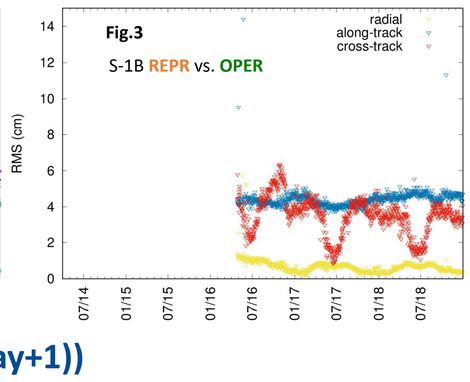
- **OPER:** Operational Sentinel orbits, IGS Final orbit and clocks used, operational GPS ARP
- **REPR:** Reprocessed Sentinel orbits based on reprocessed GPS orbits and clocks
  - Fully consistent with ITRF14/IGS14
  - 36h arc length
- **AMBF:** Reprocessed Sentinel orbits based on GRGS Final GPS orbits and clocks used together with the WSB for single-receiver ambiguity-fixing

REPR and **AMBF** apply new GPS ARP and new estimated PCO.

Comparison to OPER solutions



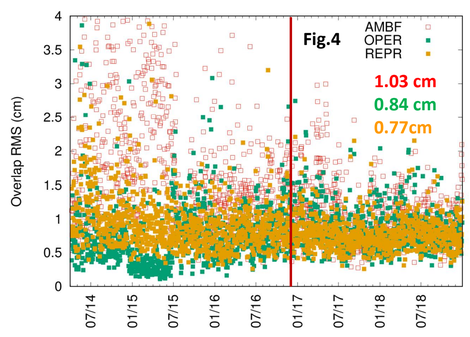


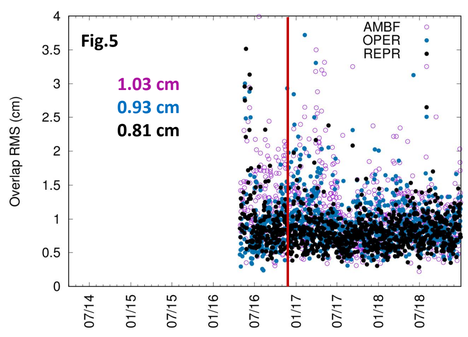


Orbit overlaps (23:00 – 01:00 (day+1))

Orbit overlaps (**Figs.4+5**) are lowest for the **REPR** solution. Mean RMS is only valid after 1 Dec 2017, because beforehand the **OPER** solution had an arc length of 48 h (instead of 32 h). Overlap statistics would not be equivalent.

It is not yet understood why the overlaps of the **AMBF** solutions are worst (under investigation).

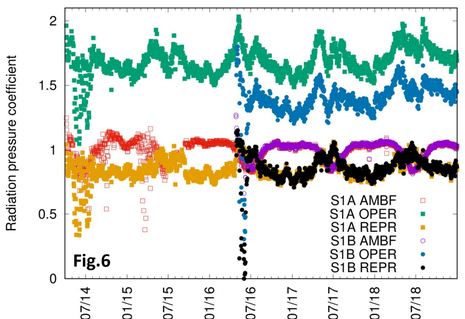


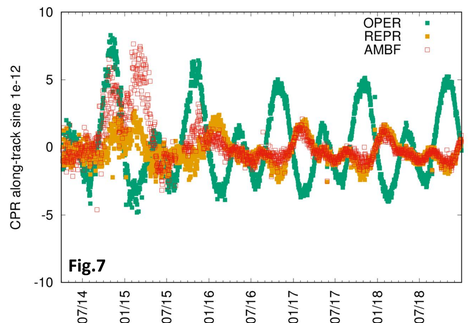


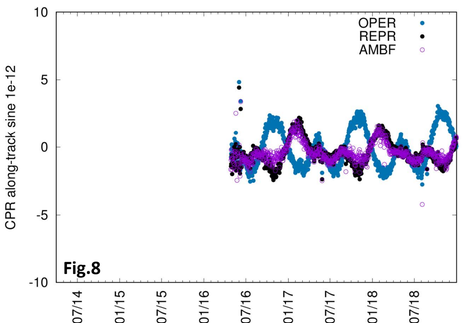
Estimated orbit parameters

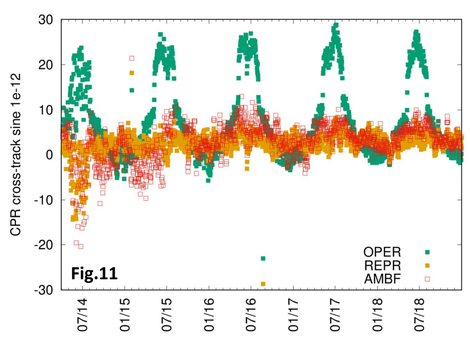
The estimated radiation pressure coefficient (**Fig.6**) becomes significantly closer to 1.0 (ideal value) for the **REPR** and **AMBF** solutions. Additionally, the values of S-1A and S-1B get very similar.

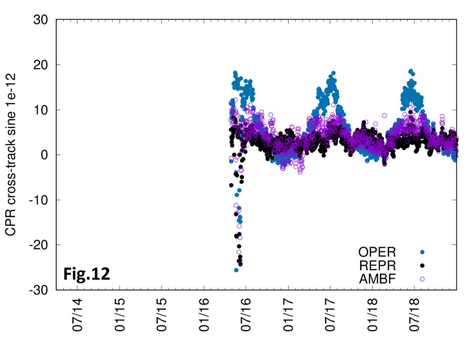
The empirical CPR parameters (**Figs.7-12**) show large systematics for the **OPER** solution, which are mainly reduced for the **REPR** and **AMBF** solutions. Equivalent to the radiation pressure coefficient the values get very similar for S-1A and S-1B. Seasonal systematics are still present for both satellites. This is probably still related to an insufficient box-wing model of the very complex Sentinel-1 satellite.



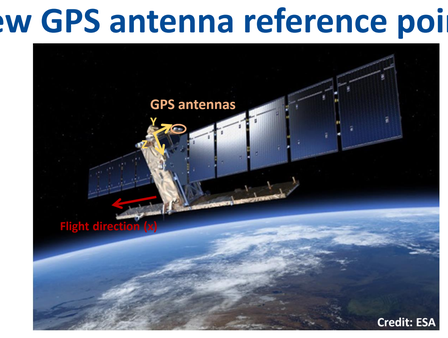








New GPS antenna reference points



	SRF	Operational values (mm)	New values (mm)	Differences (mm)
GPS Antenna 1	X	-976.2	**-937.1**	**39.1**
	Y	286.9	**332.1**	**45.2**
	Z	124.1	**131.0**	**6.9**
GPS Antenna 2	X	-985.5	**-946.5**	**39.0**
	Y	513.5	**558.7**	**45.2**
	Z	229.3	**236.2**	**6.9**

Due to a mismatch in documentation wrong GPS antenna reference points (ARP) are used for the Sentinel-1 satellites in the operational processing. The table above lists the different values (in Satellite Reference Frame (SRF)) and the discrepancies between the two ARP sets. The reprocessed Sentinel-1 orbit solutions are based on the new values, whereas operational constraints still prevent to switch to the new ARPs for the operational orbit solutions.

In addition, new phase center offsets (PCO) are estimated and listed in the table below (in Antenna Reference Frame (ARF)).

PCO coordinates in ARF – X/Y/Z (mm)		
	Operational values (mm)	New values (mm)
S-1A	-0.50 / 1.00 / 68.00	**-1.98 / -11.22 / 59.80**
S-1B	-0.50 / 1.00 / 68.00	**-3.48 / -21.13 / 51.92**

Comparison to **OPER** solutions show the large differences (**Fig.1**) due to the corrected GPS ARP and the PCO. In addition, systematic seasonal differences in cross-track direction can be noticed (**Figs.2+3**).

Comparison to QWG orbit solutions

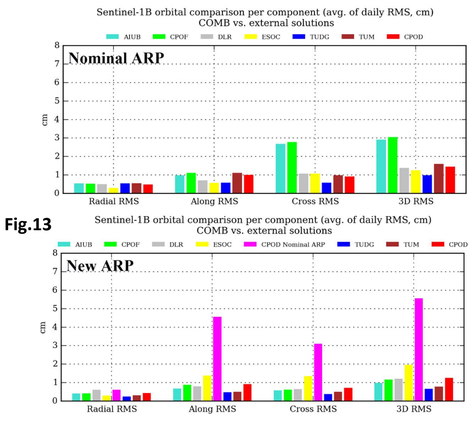
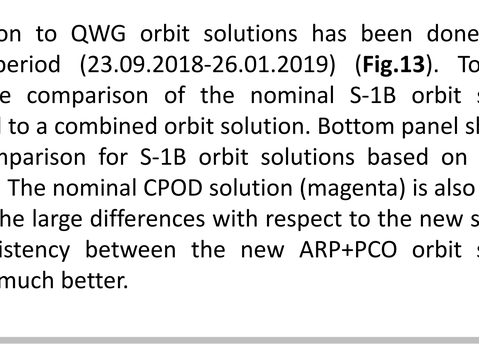


Fig.13



Comparison to QWG orbit solutions has been done for the RSR#13 period (23.09.2018-26.01.2019) (**Fig.13**). Top panel shows the comparison of the nominal S-1B orbit solutions compared to a combined orbit solution. Bottom panel shows the same comparison for S-1B orbit solutions based on the new ARP+PCO. The nominal CPOD solution (magenta) is also included showing the large differences with respect to the new solutions. The consistency between the new ARP+PCO orbit solutions becomes much better.

Summary

The Copernicus POD Service has performed an offline reprocessing of the Sentinel-1 orbit solutions. Next to background model updates the correct GPS ARP + PCO (estimated) have been used leading to large orbit differences of up to 10 cm.

The reprocessed orbit time series gets more consistent for the two satellites. Large systematics in the estimated orbit parameters are removed and the parameters get very similar for both satellites (expected due to the identical construction).

Comparison to QWG orbit solutions reveal the better consistency of the different orbits solutions when switching to the new GPS ARP+PCO.

The Copernicus POD Service recommends to switch to the correct Sentinel-1 GPS ARPs to provide an even better orbit quality. The reprocessed time series will of course support such a switch to avoid a large jump in the orbit time series.

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Poster compiled by H. Peter, May 2019
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