

# Orbit determination of the Sentinel satellites – preparation for GPS L2C-tracking

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## Introduction and orbit accuracy

The Copernicus POD (precise orbit determination) Service is an operational service to provide accurate orbit and attitude products for the Sentinel-1, -2, and -3 missions.

Currently, four Sentinel satellites – 1A, 1B, 2A, 3A – are processed operationally. Sentinel-2B is in the commissioning phase and first data have been processed.

Table 1 lists the different orbit products of the different missions and their accuracy requirements.

The validation of the orbit accuracy is mainly done by comparing the orbits to external solutions delivered by the Copernicus POD Quality Working Group. The members of this group use different software packages and different parametrizations for their solutions.

Sentinel-3A is the only satellite carrying a laser retro reflector and a DORIS receiver, which allows for independent validation by another observation technique.

Figure 1 shows the mean RMS values of an orbit comparison for a 4-month period of the corresponding NTC (non-time critical) orbits vs. external QWG solutions. Figure 2 shows the residuals of Satellite Laser Ranging measurements compared to the S-3A NTC orbits. The figures show that the accuracy requirements are fulfilled for all missions.

## Copernicus POD Service

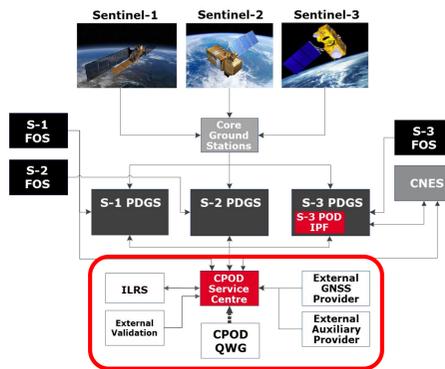


Table1: Orbit products and accuracy requirements

Mission	Category	Orbit Accuracy (RMS)
S-1	NRT	10 cm (2D)
	NTC	5 cm (3D)
S-2	NRT (predicted)	3 m (2D)
	NRT	1 m (3D)
S-3	NRT (S3PODIPF)	10 cm radial (target of 8 cm)
	STC	4 cm radial (target of 3 cm)
	NTC	3 cm radial (target of 2 cm)

## Preparation for GPS-L2C tracking

Focus of this poster is the preparation of the service to future GPS-L2C tracking of the Sentinel GPS receivers.

The GPS receivers on the B-satellites have the capability to track the L2C signal. The option is, however, not yet activated, because if enabled the old L2 signal can no longer be tracked by the receiver. The measurements of many old GPS IIA and IIR satellites would have to be discarded because of the missing second frequency.

For a short test, the redundant GPS receiver on Sentinel-1B has been switched to the L2C configuration and has delivered data in parallel to the main receiver. This data set of ~6 min has been analysed.

Currently, 19 GPS satellites (GPS-IIRM and GPS-IIF) are capable to transmit the L2C signal whereas 12 satellites (GPS-IIR) are not. Simulations are done to see whether this number of satellites is sufficient to deliver enough tracking data for POD or whether more L2C capable GPS satellites are needed to get sufficient data for reliable POD of the Sentinel satellites.

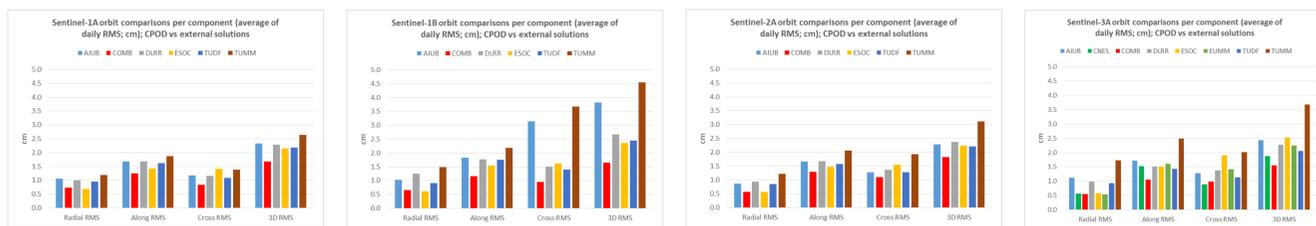


Figure 1: Mean RMS values (cm) of orbit comparison to external solutions from POD QWG (1.10.2016- 31.1.2017)

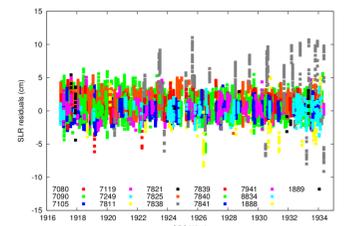


Figure 2: SLR residuals (cm) of S-3A NTC orbits from 1.10.2016- 31.1.2017; Mean 0.78 cm, RMS 1.88 cm

## GPS L2C tracking test on Sentinel-1B

During the commissioning phase of Sentinel-1B a L2C tracking test has been performed (8 September 2016). The redundant GPS receiver has been switched on and the L2C tracking has been enabled to deliver data in parallel to the nominal operational receiver. Unfortunately, the test data set is only ~6 min long.

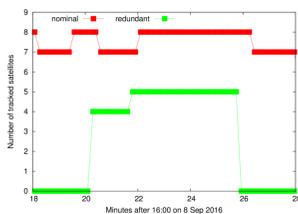


Figure 3: Number of tracked satellites (two frequencies available) on S-1B during the L2C test; redundant receiver tracked only L2C capable satellites

The number of tracked satellites shown in Fig.3 is smaller for the redundant receiver, because the number of L2C capable GPS satellites is only 19 compared to the full constellation of 31 satellites.

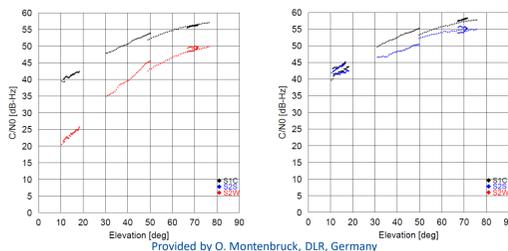


Figure 4: Signal-to-noise (C/N<sub>0</sub>) values for measurements from main (left) and redundant (right) receiver; L1 C/A (black), L2 P(Y) (red), L2C (blue)

Figure 4 displays the signal-to-noise values for the different observables. The higher C/N<sub>0</sub> values for the L2C signal (blue) than for the L2 P(Y) signal (red) are expected.

The L2C test data set is too short to use the observations for an orbit determination. To test the performance at least of the reduced number of observations on the orbit results, an L2C only orbit determination is simulated by excluding all observations to non L2C capable satellites from the data of the nominal receiver. Fig.4 (left) shows the histogram for the number of tracked satellites in the L2C only case (green) as well as the nominal case (red). The nominal and L2C satellites only orbit solutions (Fig.4 (right)) are very similar except for the last half hour of the day, where the number of tracked satellites drops to two for the L2C sat only solution.

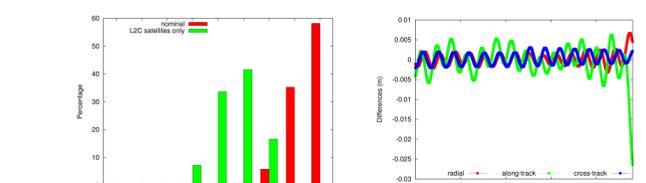


Figure 5: Left: Number of tracked satellites for the L2C satellites only (red) and the nominal case (green); right: orbit differences between the nominal and the orbit solution based on the L2C satellites only

## Simulations of S-3A GPS observations based on different number of GPS satellites

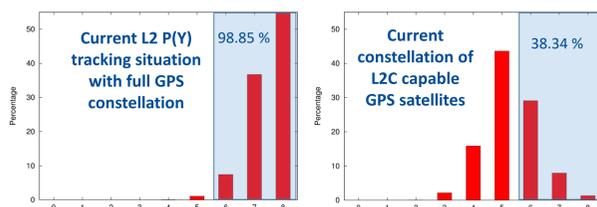


Figure 6: Percentage of epochs with corresponding number of available observations; left: current tracking situation (L2 P(Y)), right: only L2C capable GPS satellites used

The number of observables per epoch is important to guarantee a stable quality of the POD products. As shown in Figure 5 the current number of available L2C capable satellites is already sufficient for most of the time. It is, however, an example for just one day and the problems in the last half hour of the day can be avoided with more L2C capable satellites in the constellation. In dependency of the number of L2C capable satellites in the constellation a simulation of S-3A GPS observations has been done with a stepwise increasing number of L2C capable GPS satellites (+2, 4, 6, and 8 satellites). A similar tracking situation as with the full L2 P(Y) availability (Figure 6, left) is not reached before 8 more L2C capable GPS satellites (Figure 7, right) are in orbit. Providing that a long term analysis does confirm, a constellation with only a few more L2C capable satellites than currently might already be fully sufficient for a switch to the L2C capability of the Sentinel receivers.

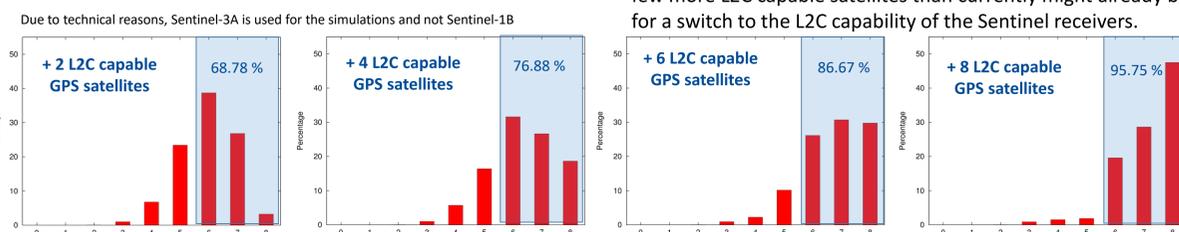


Figure 7: Percentage of epochs with corresponding number of available observations; left: current L2C satellites; second left: current L2C satellites + 4; second right: current L2C satellites + 6; right: current L2C satellites + 8

## Summary

The POD processes of the Sentinel satellites are running smoothly at the Copernicus POD Service. The orbit accuracy requirements are fulfilled for all missions.

The GPS receivers on the B-satellites are capable to track the new L2C signal, however, exclusively. A short tracking test on S-1B revealed no processing problems, but it was too short for a thorough analysis. A longer test should be envisaged (on S-1B or S-2B) to show the long-term performance. Simulations with a step-wise increased number of L2C capable GPS satellites show that at least 8 more L2C capable GPS satellites are needed in the constellation to get a similar tracking performance as with the current full constellation.

The impact of the L2C tracking performance on the resulting orbit performance has to be further investigated for all Sentinels but only few more L2C capable satellites might be sufficient to provide orbit products on the same level of accuracy as with the current L2P(Y) constellation.



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