SENTINEL-1 POD PRODUCTS PERFORMANCE

COPERNICUS SENTINEL-1, -2 AND -3 PRECISE ORBIT DETERMINATION SERVICE (SENTINELSPOD)

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DOCUMENT STATUS SHEET

Version	Date	Pages	Changes
1.0	17/07/2013	11	First version of the document
1.1	06/09/2013	9	Version of the document after the S1 SDR Addition in Section 3 of error budget table and references to the Cal/Val where the tasks to compute the metrics to complete the error budget table are described (GMESPOD-S1-SDR_53, GMESPOD-S1-SDR_58, GMESPOD-S1-SDR_59)
1.2	28/02/2014	9	Update for S-1 ORR with common comments from S-2 and S-3 SDRs • Update of applicable and reference documents • Correct purpose of document (GMESPOD-S2-SDR-28). Section 1.1 • Addition of reference to the products handbook and link to the processing baseline (GMESPOD-S3-SDR-112) • Addition of estimated accuracy for other sources of products (CNES, ESOC,…) (GMESPOD-S3-SDR-113)
1.3	01/10/2014	9	Update for S-1 IOCR • Update applicable and reference documents in section 1.4 • Update estimated accuracy during S-1A commissioning phase in table 3-2
1.4	27/03/2015	10	Update after SRM-1: • Reference documents added • Results of SRM-1 included in table 3-2
1.5	17/05/2017	11	Update after RSR#7: • Applicable documents updated in section 1.4.1 • Reference documents added in section 1.4.2 • Results of up-to-date RSRs included in table 3-2
1.6	17/12/2019	18	Changes: • To include list of acronyms (section 1.3) • To update applicable and reference documents (section 1.4.1) • To include new values up to September 2019 (section 3) • To include plots with the evolutions (section 3.7)
1.7	18/05/2020	22	Update after RSR#16: • To update applicable and reference documents (section 1.4.1) • To include the description of the new S-1 predicted products (section 2.2) • To include the performance of the new S-1 predicted products (section 3) • To include the new values of the RSR#16 (section 3.6) • To update the plots with the evolutions (section 3.7)
1.8	04/08/2020	23	Update after RSR#017: • To update applicable and reference documents (section 1.4.1) • To include the new values of the RSR#17 (section 3.7) • To update the plots with the evolutions (section 3.8)

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1. INTRODUCTION

1.1. PURPOSE

This document presents the Sentinel-1 POD Products Performance. It describes the performance of each of the POD products generated for Sentinel-1 as compared to the POD requirements (position accuracy, coverage, timeliness, latency). The Cal/Val plan of the Sentinel-1 mission [AD.2] presents completely the calibration and validation tasks aimed at characterising the accuracy of the Sentinel-1 POD products. As part of the Cal/Val tasks, different reports are generated that justify the values presented in this document. Morevover, the Sentinel-1 POD products Quality Control Plan [AD.3] also provides information about metrics computed routinely related to the accuracy of the Sentinel-1 POD products.

This document is intended as a living document that describes the accuracy of a set of POD products for Sentinel-1 generated with a given POD system version. Thus, different accuracies are described for each processing baseline (POD system version and input data). Additional information is added to this document when a new processing baseline is used.

1.2. SCOPE

This document is a deliverable by GMV in the frame of the Provision of the Precise Orbit Determination Service for the Sentinel -1 mission.

1.3. DEFINITIONS AND ACRONYMS

Acronyms used in this document and needing a definition are included in the following table:

Table 1-1: Acronyms

Acronym	Definition	Acronym	Definition
AD	Applicable Document	NTC	Non Time Critical
AIUB	Astronomical Institute University of Bern	ORR	Operational Readiness Review
ANX	Ascending Node Crossing	OSV	Orbit State Vector
ARP	Antenna Reference Point	PDGS	Payload Data Ground Segment
CNES	Centre National d'Études Spatiales	POD	Precise Orbit Determination
CPOD	Copernicus POD	POE	Precise Orbit Ephemeris
DIL	Document Item List	PRE	Predicted
DLR	Deutsche Zentrum für Luft- und Raumfahrt	QWG	Quality Working Group
ERS	European Remote Sensing	RD	Reference Document
ESA	European Space Agency	RMS	Root Mean Square
ESOC	European Space Operation Centre	RSR	POD Regular Service Review
FTP	File Transfer Protocol	SAR	Synthetic Aperture Radar
GHOST	GPS High Precision Orbit Determination Software Tools	SDR	Software Defined Radio
GIPSY	Gps Inferred Positioning SYstem software	SPOD	Sentinels POD
GMES	Global Monitoring for Environment and Security	SPOT	Satellite pour l'Observation de la Terre
GNSS	Global Navigation Satellite System	SRM	Service Review Meeting
GPS	Global Positioning System	STC	Short Time Critical
IOCR	In-Orbit Commissioning Phase Review	SW	Software
IPF	Instrument Processing Facility	TD	Technical Documentation
MSI	Multi-Spectral Instrument	TN	Technical Note
MWR	Micro-Wave Radiometer	TUD	Technische Universiteit Delft

Acronym	Definition	Acronym	Definition
NAPEOS	NAvigation Package for Earth Orbiting Satellites	TUM	Technische Universität München
NRT	Near Real Time		

1.4. APPLICABLE AND REFERENCE DOCUMENTS

1.4.1. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [AD.X]:

Table 1-2: Applicable Documents

Ref.	Title	Code	Version	Date
[AD.1]	Sentinels POD Service File Format Specification	GMES-GSEG-EOPG-FS-10-0075	1.24	19/11/2019
[AD.2]	Sentinel-1 POD Cal-Val Plan	GMV-GMESPOD-TN-0006	1.3	02/04/2014
[AD.3]	Sentinels POD Service S-1 Products Quality Control Plan	GMV-GMESPOD-TN-0003	1.2	28/02/2014
[AD.4]	Sentinels POD Product Handbook	GMV-GMESPOD-TN-0009	1.14	18/05/2020
[AD.5]	CPOD – Quality Working Group #8	GMV-GMESPOD-MOM-QWG-08	1.0	26/06/2019

1.4.2. REFERENCE DOCUMENTS

The following documents, although not part of this document, extend or clarify its contents. Reference documents are those not applicable and referenced within this document. They are referenced in this document in the form [RD.X]:

Table 1-3: Reference Documents

Ref.	Title	Code	Version	Date
[RD.1]	Sentinel-1A Commissioning Phase POD Report	GMV-GMESPOD-TN-0018	1.0	01/10/2014
[RD.2]	Copernicus POD Service Review Meeting 1	GMV-GMESPOD-SRM-0001	1.1	27/03/2015
[RD.3]	Copernicus POD Regular Service Review Feb-May 2015	GMV-GMESPOD-RSR-0002	1.1	03/11/2015
[RD.4]	Copernicus POD Regular Service Review Jun-Sep 2015	GMV-GMESPOD-RSR-0003	1.1	18/12/2015
[RD.5]	Copernicus POD Regular Service Review Oct 2015-Jan 2016	GMV-GMESPOD-RSR-0004	1.1	01/04/2016
[RD.6]	Copernicus POD Regular Service Review Feb-May 2016	GMV-GMESPOD-RSR-0005	1.0	01/07/2016
[RD.7]	Copernicus POD Regular Service Review Jun-Sep 2016	GMV-GMESPOD-RSR-0006	1.1	22/11/2016
[RD.8]	Copernicus POD Regular Service Review Oct 2016-Jan 2017	GMV-GMESPOD-RSR-0007	1.0	03/03/2017
[RD.9]	Copernicus POD Regular Service Review Feb-May 2017	GMV-GMESPOD-RSR-0008	1.1	28/07/2017
[RD.10]	Copernicus POD Regular Service Review Jun-Sep 2017	GMV-GMESPOD-RSR-0009	1.0	30/10/2017
[RD.11]	Copernicus POD Regular Service Review Oct 2017 - Jan 2018	GMV-GMESPOD-RSR-0010	1.1	07/03/2018
[RD.12]	Copernicus POD Regular Service Review Feb-May 2018	GMV-GMESPOD-RSR-0011	1.1	31/07/2018
[RD.13]	Copernicus POD Regular Service Review Jun-Sep 2018	GMV-GMESPOD-RSR-0012	1.0	31/10/2018
[RD.14]	Copernicus POD Regular Service Review Oct 2018 - Jan 2019	GMV-GMESPOD-RSR-0013	1.0	01/03/2019
[RD.15]	Copernicus POD Regular Service Review Feb-May 2019	GMV-GMESPOD-RSR-0014	1.1	19/07/2019

Ref.	Title	Code	Version	Date
[RD.16]	Copernicus POD Regular Service Review Jun-Sep 2019	GMV-GMESPOD-RSR-0015	1.0	31/10/2019
[RD.17]	Copernicus POD Regular Service Review Oct 2019 - Jan 2020	GMV-GMESPOD-RSR-0016	1.0	04/03/2020
[RD.18]	Copernicus POD Regular Service Review Feb-May 2020	GMV-GMESPOD-RSR-0017	1.1	04/08/2020

2. COPERNICUS POD SERVICE CONTEXT

2.1. COPERNICUS POD SERVICE OVERVIEW

The **Copernicus program** (formerly known as GMES, Global Monitoring for Environment and Security) is a joint initiative of the European Commission and the European Space Agency (ESA), designed to support a sustainable European information network by monitoring, recording and analysing environmental data and events around the globe. The Copernicus program will consist of five different families of satellites.

The first family is **Sentinel-1**, which consists of two satellites with imaging C-band radars. This family continues the C-band SAR data gathered by ERS and Envisat missions. The second family is **Sentinel-2**, which consists of two satellites with optical sensors. This family continues providing the products delivered by Landsat and SPOT missions. The main instrument of the Sentinel-2 satellites is the Multi-Spectral Instrument (MSI), which operates from the visible to the shortwave infrared. The last family of the Copernicus program taken into consideration here is the **Sentinel-3**, which consists of two satellites with several sensors to continue the products of Envisat and ERS missions. Following are the products to be provided by the Sentinel-3 mission: surface colour products, surface temperature products, land vegetation products, surface topography products, which are derived from the combination of data produced by the Radar Altimeter, MWR and GNSS receiver.

The **Copernicus POD (CPOD) Service** is part of the **PDGS Ground Segment** of the Sentinels missions and is in charge of the generation of precise orbital products and auxiliary data files for their use as part of the processing chains of the respective Sentinel PDGS. The Copernicus POD Service is a service **developed and operated by GMV** with a system running on a cloud environment and providing products for the Sentinel missions with various timeliness: near real-time (NRT), short-time critical (STC), non-time critical (NTC) and reprocessing. On the other hand, the **S-3 POD IPF** is a software developed as part of the Copernicus POD Service that runs at the S-3 PDGS generating near-real time orbits for the Sentinel-3 mission.

2.2. SENTINEL-1 CPOD SERVICE PRODUCTS PERFORMANCE OVERVIEW

The main POD products generated by the CPOD Service associated to the Sentinel-1 mission are: the **predicted orbit file**, **restituted orbit file**, **precise orbit ephemerides** and **restituted attitude data**. The following performance requirements are defined for each of these products [AD.1]:

- **Predicted Orbit File**:
    - The position accuracy threshold is 1 m 2D 1-sigma RMS. The 2D refers to the along-track and cross-track directions.
    - The file is generated within 30 minutes from the reception of GNSS data in the POD FTP server.
    - The file coverage is four orbits from the last ascending node crossing (ANX) present in the GPS L0 input file.
- **Restituted Orbit File**:
    - The position accuracy threshold is 10 cm 2D 1-sigma RMS. The 2D refers to the along-track and cross-track directions.
    - The file is generated within 3 hours from reception of GNSS data in the POD FTP server.
    - The file coverage is one satellite orbit, from ascending node plus an overlap of 593 OSV before the satellite orbit time span.
- **Precise Orbit Ephemerides**:
    - The position accuracy threshold is 5 cm 3D 1-sigma RMS for S-1 POE orbit files.
    - Each file covers 26 hours (one complete day plus 1 hour before the start and after the end of the day– overlap of two hours between consecutive files).
    - Files are delivered within 20 days after data acquisition.

- **Restituted Attitude Data**:
  - The accuracy of the restituted attitude shall be better than 0.005 deg in roll, pitch and yaw independently.
  - The timeliness is the same as for the Sentinel-1 Restituted Orbit files production.
  - The coverage is the same as the Sentinel-1 Restituted Orbit file.
  - Due to inconsistencies in the accuracy of the attitude product, ESA requested not to circulate them until these inconsistencies are fixed.

Aside from the previous POD products, there are others such as POD products quality reports, including GNSS sensor performance monitoring information, or anomaly reports. This second set of products do not have performance requirements as those mentioned above for the orbital and auxiliary products for the Sentinel-1 mission.

3. SENTINEL-1 PRODUCTS PERFORMANCE

This section describes the performance of each of the POD products generated for Sentinel-1 as compared to the POD requirements (position accuracy, coverage, timeliness, latency). The Cal/Val plan of the Sentinel-1 mission [AD.2] presents completely the calibration and validation tasks aimed at characterising the accuracy of the Sentinel-1 POD products. As part of the Cal/Val tasks, different reports are generated that justify the values presented in this document. Morevover, the Sentinel-1 POD products Quality Control Plan [AD.3] also provides information about metrics computed routinely related to the accuracy of the Sentinel-1 POD products.

The following table presents the requirements of the Sentinel-1 POD products:

Table 3-1: Requirements table for the Sentinel-1 POD products

Product	Latency	Requirement metric	Requirement value
Predicted orbit file (AUX_PREORB)	NRT	position accuracy in 2D (along- and cross-track) 1-sigma RMS	1 m
Restituted orbit file (AUX_RESORB)	NRT	position accuracy in 2D (along- and cross-track) 1-sigma RMS	10 cm
Precise orbit ephemerides (AUX_POEORB)	NTC	position accuracy in 3D 1-sigma RMS	5 cm
Attitude restituted data (AUX_RESATT)	NTC	Roll, pitch and yaw accuracy in 1-sigma RMS independently	0.005 deg

The tables of the following sub sections present the estimated accuracy of the POD products associated to a given processing baseline. A processing baseline is composed by a system version (software and configuration), and a set of input data. The description of the processing baselines in terms of models, changes with respect to other processing baselines, inputs and output coverage, etc., is provided in the POD product handbook [AD.4]. The source column of the tables indicates the centre generating the product, which are listed in Table 3-2.

Table 3-2: Description of orbit solutions

Name	Centre	POD SW
AIUB	Astronomical Institute University of Bern	Bernese
AING	Astronomical Institute University of Bern	Bernese (Non-gravitational)
COMB	ALL	ALL
CPOD	Copernicus POD Service – GMV	NAPEOS
DLR	Deutsche Zentrum für Luft- und Raumfahrt	GHOST
ESOC	European Space Operation Centre	NAPEOS
TUDF	Technische Universiteit Delft	GHOST
TUDG	Technische Universiteit Delft	GIPSY
TUM	Technische Universität München	Bernese

The following tables and plots show different metrics:

1. Average and standard deviation of the comparisons over the time period reported.
2. The 1-sigma (68%), 2-sigma (95%) and 3-sigma (99.7%) of the predicted (PRE) and NRT comparisons over the time period reported.

In order not to harm the statistics of the comparisons due to degraded products from manoeuvres or gaps of data, a filetering criterion has been included. Thus, comparisons above two times the accuracy requirement of the products have been filtered-out.

3.1. 2014

Table 3-3: Estimated accuracy of CPOD products for May – August 2014 [RD.1]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean (cm)	S-1B Mean (cm)
SPOD_SYSTEM_v0.8.4	NRT [2D RMS]	CPOD vs. NTC	7.4	N/A
		CPOD vs. ESOC	7.6	N/A
		CPOD vs. DLR	8.6	N/A
	NTC [3D RMS]	CPOD vs. ESOC	5.5	N/A
		CPOD vs. DLR	8.1	N/A
		CPOD vs. ESOC	5.0	N/A
		CPOD vs. DLR	7.4	N/A

3.2. 2015

Table 3-4: Estimated accuracy of CPOD products for January 2015 [RD.2]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean (cm)	S-1B Mean (cm)
SPOD_SYSTEM_v0.8.8	NRT [2D RMS]	CPOD vs. ESOC	3.76	N/A
	NTC [3D RMS]	CPOD vs. AIUB	4.33	N/A
		CPOD vs. DLR	6.45	N/A
		CPOD vs. ESOC	2.71	N/A
		CPOD vs. TUD	4.75	N/A
		CPOD vs. TUM	3.42	N/A
		CPOD vs. COMB	**2.37**	**N/A**

Table 3-5: Estimated accuracy of CPOD products for February – May 2015 [RD.3]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean (cm)	S-1B Mean (cm)
SPOD_SYSTEM_v0.8.8 SPOD_SYSTEM_v0.8.9 SPOD_SYSTEM_v0.9.0	NRT [2D RMS]	CPOD vs. ESOC	2.89	N/A
SPOD_SYSTEM_v0.8.9	NTC [3D RMS]	CPOD vs. AIUB	4.34	N/A
		CPOD vs. DLR	5.76	N/A
		CPOD vs. ESOC	2.34	N/A
		CPOD vs. TUDF	5.98	N/A
		CPOD vs. TUM	3.62	N/A

Table 3-6: Estimated accuracy of CPOD products for June – September 2015 [RD.4]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean (cm)	S-1B Mean (cm)
SPOD_SYSTEM_v0.9.0 SPOD_SYSTEM_v0.9.1 SPOD_SYSTEM_v0.9.2 SPOD_SYSTEM_v0.9.3 SPOD_SYSTEM_v0.9.4	NRT [2D RMS]	CPOD vs. ESOC	3.81	N/A

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean (cm)	S-1B Mean (cm)
SPOD_SYSTEM_v0.9.1 SPOD_SYSTEM_v0.9.2	NTC [3D RMS]	CPOD vs. AIUB	2.95	N/A
		CPOD vs. DLR	4.30	N/A
		CPOD vs. ESOC	2.21	N/A
		CPOD vs. TUDF	2.52	N/A
		CPOD vs. TUM	2.59	N/A

Table 3-7: Estimated accuracy of CPOD products for October 2015 – January 2016 [RD.5]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean (cm)	S-1B Mean (cm)
SPOD_SYSTEM_v0.9.4 SPOD_SYSTEM_v0.9.5 SPOD_SYSTEM_v0.9.6 SPOD_SYSTEM_v0.10.0	NRT [2D RMS]	CPOD vs. ESOC	4.30	N/A
SPOD_SYSTEM_v0.9.6 SPOD_SYSTEM_v0.10.0	NTC [3D RMS]	CPOD vs. AIUB	2.45	N/A
		CPOD vs. DLR	3.89	N/A
		CPOD vs. ESOC	1.53	N/A
		CPOD vs. TUDF	2.11	N/A
		CPOD vs. TUM	2.75	N/A
		CPOD vs. COMB	**1.82**	**N/A**

3.3. 2016

Table 3-8: Estimated accuracy of CPOD products for February – May 2016 [RD.6]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
SPOD_SYSTEM_v0.10.0 SPOD_SYSTEM_v1.0.0 SPOD_SYSTEM_v1.0.1 SPOD_SYSTEM_v1.0.2 SPOD_SYSTEM_v1.0.3 SPOD_SYSTEM_v1.0.4 SPOD_SYSTEM_v1.0.5 SPOD_SYSTEM_v1.0.6 SPOD_SYSTEM_v1.0.7 SPOD_SYSTEM_v1.0.8	NRT [2D RMS]	CPOD vs. ESOC	3.71 ± 1.52 (av) 4.15 (1-sigma) 5.67 (2-sigma) 15.60 (3-sigma)	N/A
	NTC [3D RMS]	CPOD vs. AIUB	2.46 ± 0.24	N/A
		CPOD vs. DLR	2.16 ± 0.25	N/A
		CPOD vs. ESOC	1.98 ± 0.49	N/A
		CPOD vs. TUDF	2.45 ± 0.43	N/A
		CPOD vs. TUM	2.47 ± 0.86	N/A
		CPOD vs. COMB	**1.83 ± 0.23**	**N/A**

Table 3-9: Estimated accuracy of CPOD products for June – September 2016 [RD.7]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
SPOD_SYSTEM_v1.0.8 SPOD_SYSTEM_v1.0.9 SPOD_SYSTEM_v1.0.10	NRT [2D RMS]	CPOD vs. ESOC	3.21 ± 1.65 (av) 3.38 (1-sigma) 5.71 (2-sigma) 11.32 (3-sigma)	2.62 ± 0.76 (av) 2.90 (1-sigma) 3.97 (2-sigma) 5.21 (3-sigma)
	NTC [3D RMS]	CPOD vs. AIUB	2.44 ± 0.28	3.87 ± 0.73
		CPOD vs. DLR	2.30 ± 0.38	2.21 ± 0.34

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
		CPOD vs. ESOC	2.44 ± 0.56	2.35 ± 0.38
		CPOD vs. TUDF	2.39 ± 0.35	2.36 ± 0.29
		CPOD vs. TUM	2.16 ± 0.24	4.13 ± 1.16
		CPOD vs. COMB	**1.84 ± 0.33**	**1.68 ± 0.30**

Table 3-10: Estimated accuracy of CPOD products for October 2016 – January 2017 [RD.8]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
SPOD_SYSTEM_v1.0.10 SPOD_SYSTEM_v1.1.0 SPOD_SYSTEM_v1.1.1 SPOD_SYSTEM_v1.2.0 SPOD_SYSTEM_v1.2.1	NRT [2D RMS]	CPOD vs. ESOC	2.93 ± 0.97 (av) 3.26 (1-sigma) 4.62 (2-sigma) 5.94 (3-sigma)	3.04 ± 0.94 (av) 3.41 (1-sigma) 4.80 (2-sigma) 6.20 (3-sigma)
	NTC [3D RMS]	CPOD vs. AIUB	2.32 ± 0.32	3.82 ± 0.72
		CPOD vs. DLR	2.28 ± 0.30	2.67 ± 0.43
		CPOD vs. ESOC	2.15 ± 0.51	2.36 ± 0.54
		CPOD vs. TUDF	2.19 ± 0.30	2.44 ± 0.48
		CPOD vs. TUM	2.65 ± 0.41	4.56 ± 0.76
		CPOD vs. COMB	**1.68 ± 0.36**	**1.65 ± 0.32**

3.4. 2017

Table 3-11: Estimated accuracy of CPOD products for February – May 2017 [RD.9]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
SPOD_SYSTEM_v1.3.0 SPOD_SYSTEM_v1.3.1 SPOD_SYSTEM_v1.3.2	NRT [2D RMS]	CPOD vs. ESOC	2.29 ± 0.70 (av) 2.55 (1-sigma) 3.56 (2-sigma) 4.56 (3-sigma)	2.58 ± 0.81 (av) 2.88 (1-sigma) 4.01 (2-sigma) 5.38 (3-sigma)
	NTC [3D RMS]	CPOD vs. AIUB	2.25 ± 0.26	3.93 ± 0.42
		CPOD vs. DLR	2.12 ± 0.29	2.26 ± 0.31
		CPOD vs. ESOC	2.13 ± 0.40	2.33 ± 0.40
		CPOD vs. TUDF	2.34 ± 0.41	2.33 ± 0.34
		CPOD vs. TUM	2.58 ± 0.49	4.79 ± 0.67
		CPOD vs. COMB	**1.56 ± 0.28**	**1.51 ± 0.33**

Table 3-12: Estimated accuracy of CPOD products for June – September 2017 [RD.10]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
SPOD_SYSTEM_v1.3.3 SPOD_SYSTEM_v1.3.4 SPOD_SYSTEM_v1.3.5 SPOD_SYSTEM_v1.3.6	NRT [2D RMS]	CPOD vs. ESOC	2.69 ± 0.93 (av) 3.09 (1-sigma) 4.39 (2-sigma) 5.46 (3-sigma)	2.66 ± 0.98 (av) 3.02 (1-sigma) 4.46 (2-sigma) 5.58 (3-sigma)
	NTC [3D RMS]	CPOD vs. AIUB	2.75 ± 0.63	4.73 ± 0.77
		CPOD vs. DLR	2.13 ± 0.71	2.07 ± 0.24
		CPOD vs. ESOC	2.60 ± 0.79	2.40 ± 0.55

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
		CPOD vs. TUDF	2.54 ± 1.18	2.34 ± 0.26
		CPOD vs. TUM	2.53 ± 0.56	2.32 ± 0.38
		CPOD vs. COMB	**1.58 ± 0.95**	**1.48 ± 0.34**

Table 3-13: Estimated accuracy of CPOD products for October 2017 – January 2018 [RD.11]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
SPOD_SYSTEM_v1.3.7 SPOD_SYSTEM_v1.3.8 SPOD_SYSTEM_v1.3.9 SPOD_SYSTEM_v1.4.0	NRT [2D RMS]	CPOD vs. ESOC	2.73 ± 0.87 (av) 3.02 (1-sigma) 4.33 (2-sigma) 5.61 (3-sigma)	2.50 ± 0.90 (av) 2.79 (1-sigma) 4.10 (2-sigma) 5.78 (3-sigma)
	NTC [3D RMS]	CPOD vs. AIUB	2.14 ± 0.34	3.97 ± 0.43
		CPOD vs. DLR	2.05 ± 0.30	2.13 ± 0.30
		CPOD vs. ESOC	1.92 ± 0.52	1.70 ± 0.47
		CPOD vs. TUDF	1.99 ± 0.29	2.05 ± 0.29
		CPOD vs. TUM	2.20 ± 0.31	2.21 ± 0.25
		CPOD vs. COMB	**1.49 ± 0.27**	**1.38 ± 0.25**

3.5. 2018

Table 3-14: Estimated accuracy of CPOD products for February – May 2018 [RD.12]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
SPOD_SYSTEM_v1.4.1 SPOD_SYSTEM_v1.4.2 SPOD_SYSTEM_v1.4.3	NRT [2D RMS]	CPOD vs. ESOC	2.52 ± 0.84 (av) 2.80 (1-sigma) 3.92 (2-sigma) 5.61 (3-sigma)	2.37 ± 0.84 (av) 2.59 (1-sigma) 3.72 (2-sigma) 5.80 (3-sigma)
	NTC [3D RMS]	CPOD vs. AIUB	2.15 ± 0.30	3.96 ± 0.50
		CPOD vs. AING	4.53 ± 1.11	3.77 ± 0.48
		CPOD vs. DLR	2.03 ± 0.34	2.10 ± 0.32
		CPOD vs. ESOC	1.79 ± 0.31	1.55 ± 0.28
		CPOD vs. TUDG	1.80 ± 0.28	1.97 ± 0.31
		CPOD vs. TUM	2.01 ± 0.30	3.97 ± 0.41
		CPOD vs. COMB	**1.40 ± 0.24**	**1.41 ± 0.30**

Table 3-15: Estimated accuracy of CPOD products for June – September 2018 [RD.13]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
SPOD_SYSTEM_v1.5.0	NRT [2D RMS]	CPOD vs. ESOC	2.60 ± 0.82 (av) 2.87 (1-sigma) 3.92 (2-sigma) 5.92 (3-sigma)	2.52 ± 0.78 (av) 2.80 (1-sigma) 3.83 (2-sigma) 5.57 (3-sigma)
	NTC [3D RMS]	CPOD vs. AING	3.91 ± 0.60	2.60 ± 0.36
		CPOD vs. AIUB	2.64 ± 0.33	4.54 ± 0.74
		CPOD vs. DLR	2.03 ± 0.21	2.10 ± 0.27

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
		CPOD vs. ESOC	2.07 ± 0.30	1.87 ± 0.36
		CPOD vs. TUDG	2.08 ± 0.25	2.37 ± 0.35
		CPOD vs. TUM	2.24 ± 0.27	2.29 ± 0.26
		CPOD vs. COMB	**1.54 ± 0.21**	**1.49 ± 0.22**

Table 3-16: Estimated accuracy of CPOD products for October 2018 – January 2019 [RD.14]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
SPOD_SYSTEM_v1.5.1 SPOD_SYSTEM_v1.5.2 SPOD_SYSTEM_v1.5.3	NRT [2D RMS]	CPOD vs. ESOC	2.54 ± 0.75 (av) 2.80 (1-sigma) 3.84 (2-sigma) 5.80 (3-sigma)	2.36 ± 0.82 (av) 2.56 (1-sigma) 3.90 (2-sigma) 5.80 (3-sigma)
	NTC [3D RMS]	CPOD vs. AIUB	2.08 ± 0.29	3.87 ± 0.44
		CPOD vs. DLR	1.96 ± 0.23	2.07 ± 0.25
		CPOD vs. ESOC	1.96 ± 0.21	1.86 ± 0.22
		CPOD vs. TUDG	1.72 ± 0.24	1.94 ± 0.22
		CPOD vs. TUM	1.85 ± 0.23	2.36 ± 0.30
		CPOD vs. COMB	**1.28 ± 0.20**	**1.45 ± 0.20**

3.6. 2019

Table 3-17: Estimated accuracy of CPOD products for February – May 2019 [RD.15]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
SPOD_SYSTEM_v1.5.4	NRT [2D RMS]	CPOD vs. ESOC	2.37 ± 0.68 (av) 2.60 (1-sigma) 3.54 (2-sigma) 5.11 (3-sigma)	2.30 ± 0.73 (av) 2.52 (1-sigma) 3.73 (2-sigma) 4.94 (3-sigma)
	NTC [3D RMS]	CPOD vs. AIUB	2.07 ± 0.20	3.99 ± 0.30
		CPOD vs. DLR	1.99 ± 0.21	2.09 ± 0.18
		CPOD vs. ESOC	2.20 ± 0.22	1.99 ± 0.21
		CPOD vs. TUDG	1.79 ± 0.23	1.97 ± 0.21
		CPOD vs. TUM	2.06 ± 0.26	2.40 ± 0.15
		CPOD vs. COMB	**1.44 ± 0.21**	**1.52 ± 0.19**

Table 3-18: Estimated accuracy of CPOD products for June – September 2019 [RD.16]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
SPOD_SYSTEM_v1.5.4	NRT [2D RMS]	CPOD vs. ESOC	2.69 ± 0.86 (av) 2.97 (1-sigma) 4.19 (2-sigma) 5.85 (3-sigma)	2.71 ± 0.85 (av) 3.03 (1-sigma) 4.29 (2-sigma) 5.50 (3-sigma)
	NTC [3D RMS]	CPOD vs. AIUB	6.62 ± 0.29	5.99 ± 0.29
		CPOD vs. DLR	6.89 ± 0.69	5.96 ± 0.35
		CPOD vs. ESOC	6.32 ± 0.69	4.84 ± 0.41

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
		CPOD vs. TUDG	7.01 ± 0.42	6.09 ± 0.23
		CPOD vs. TUM	7.27 ± 0.38	6.42 ± 0.27
		CPOD vs. COMB	**6.29 ± 0.59**	**5.24 ± 0.40**

Table 3-19: Estimated accuracy of CPOD products for October 2019 – January 2020 [RD.17]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
SPOD_SYSTEM_v1.5.5	PRE [2D RMS]	CPOD vs. ESOC	9.51 ± 9.08 (av) 9.71 (1-sigma) 15.76 (2-sigma) 99.20 (3-sigma)	8.59 ± 8.21 (av) 8.92 (1-sigma) 15.25 (2-sigma) 76.13 (3-sigma)
SPOD_SYSTEM_v1.5.4 SPOD_SYSTEM_v1.5.5	NRT [2D RMS]	CPOD vs. ESOC	4.62 ± 2.38 (av) 6.51 (1-sigma) 7.50 (2-sigma) 8.69 (3-sigma)	3.61 ± 1.56 (av) 4.68 (1-sigma) 5.82 (2-sigma) 7.75 (3-sigma)
	NTC [3D RMS]	CPOD vs. AING	6.06 ± 0.31	5.26 ± 0.18
		CPOD vs. AIUB	5.96 ± 0.29	5.10 ± 0.16
		CPOD vs. DLR	7.19 ± 0.33	5.90 ± 0.24
		CPOD vs. ESOC	6.80 ± 0.31	4.96 ± 0.30
		CPOD vs. TUDG	6.92 ± 0.26	5.77 ± 0.21
		CPOD vs. TUM	6.63 ± 0.36	5.49 ± 0.29
		CPOD vs. COMB	**6.36 ± 0.31**	**5.14 ± 0.23**

Note: the jump on the NTC comparisons between period Feb-May 2019 (around 1.5 cm), Jun-Sep 2019 (around 6 cm), and Oct 2019-Jan 2020 (around 6 cm) is due to the change of the configuration used by the CPOD QWG [AD.5], to use a new location of the GPS Antenna Reference Point (ARP). The Operational CPOD solution cannot be changed for the moment, until ESA agrees with the change. A similar comment can be done for the NRT comparisons (and the new predicted comparisons) between period Oct 2019-Jan 2020 (jump of around 2 cm in mean) since ESOC changed the ARP configuration of their orbit solutions, whereas the CPOD products remain using the old one.

3.7. 2020

Table 3-20: Estimated accuracy of CPOD products for February – May 2020 [RD.18]

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
SPOD_SYSTEM_v1.5.5 SPOD_SYSTEM_v1.6.0	PRE [2D RMS]	CPOD vs. ESOC	10.33 ± 7.73 (av) 10.45 (1-sigma) 16.40 (2-sigma) 67.98 (3-sigma)	9.17 ± 7.72 (av) 9.26 (1-sigma) 16.48 (2-sigma) 82.34 (3-sigma)
	NRT [2D RMS]	CPOD vs. ESOC	6.88 ± 0.74 (av) 7.10 (1-sigma) 7.93 (2-sigma) 9.55 (3-sigma)	4.97 ± 0.83 (av) 5.18 (1-sigma) 6.13 (2-sigma) 8.43 (3-sigma)
	NTC [3D RMS]	CPOD vs. AING	6.30 ± 0.49	5.52 ± 0.43
		CPOD vs. AIUB	6.15 ± 0.47	5.33 ± 0.42
		CPOD vs. DLR	7.21 ± 0.28	5.94 ± 0.25

Processing baseline identifier [AD.4]	Product type	Source	S-1A Mean ± stdev (cm)	S-1B Mean ± stdev (cm)
		CPOD vs. ESOC	6.72 ± 0.29	4.69 ± 0.26
		CPOD vs. TUDG	6.94 ± 0.32	5.76 ± 0.29
		CPOD vs. TUM	6.90 ± 0.50	5.82 ± 0.52
		CPOD vs. COMB	**6.37 ± 0.42**	**5.12 ± 0.35**

Note: the jump on the NTC comparisons between period Feb-May 2020 (around 6 cm) is due to the change of the configuration used by the CPOD QWG [AD.5], to use a new location of the GPS Antenna Reference Point (ARP). The ARP will be changed soon after an agreement with ESA. A similar comment can be done for the NRT comparisons (and the predicted comparisons) between period Feb-May 2020 (jump of between 3-5 cm in mean) since ESOC changed the ARP configuration of their orbit solutions, whereas the CPOD products remain using the old one.

3.8. OVERALL

The following figures show the averages and 1-sigma and 3-sigma reported in the previous tables.

3.8.1. PRE

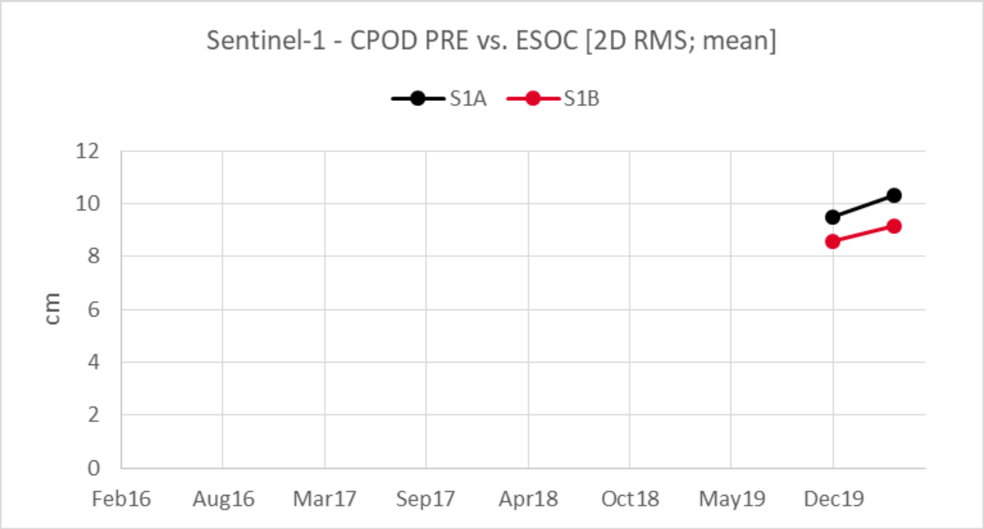

Figure 3-1: Sentinel-1 CPOD PRE vs. ESOC [2D RMS; mean] (cm)

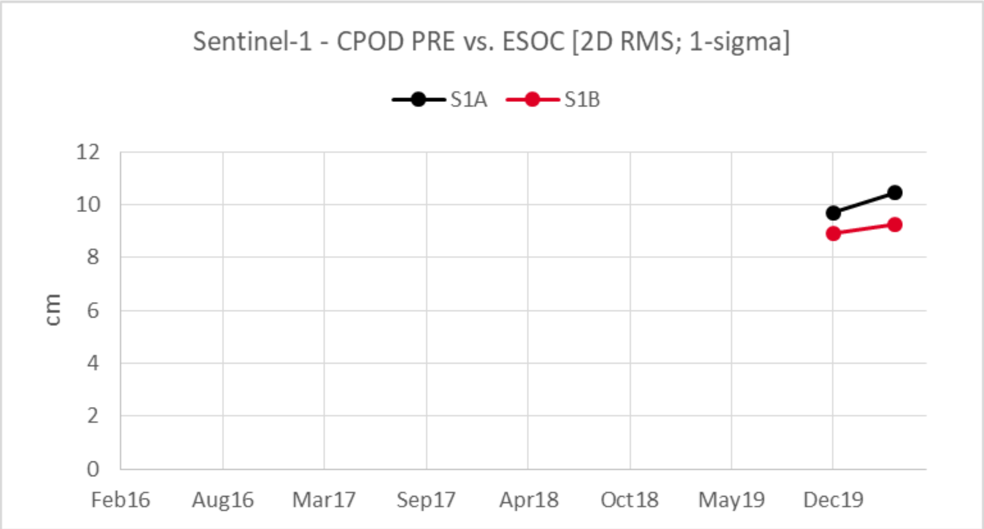

Figure 3-2: Sentinel-1 CPOD PRE vs. ESOC [2D RMS; 1-sigma] (cm)

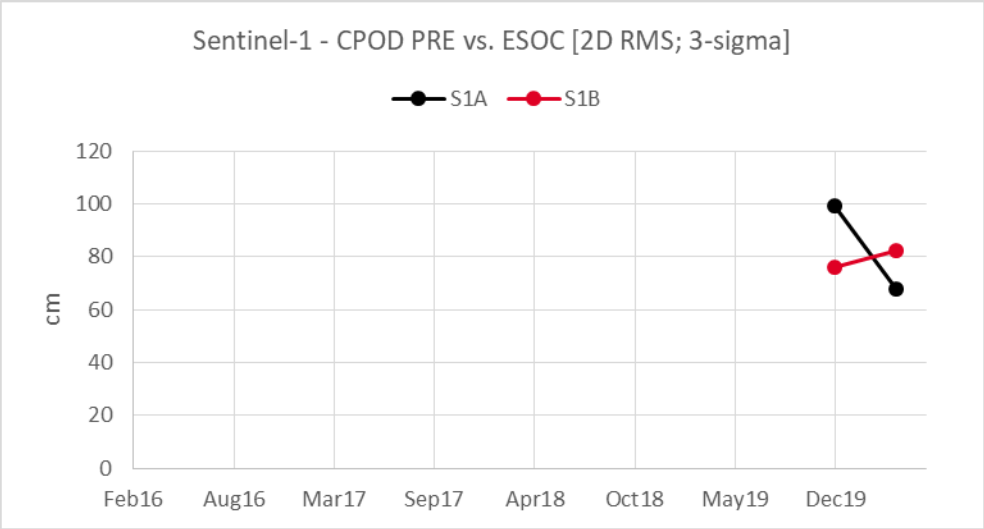

Figure 3-3: Sentinel-1 CPOD PRE vs. ESOC [2D RMS; 3-sigma] (cm)

Note: the values shown on Dec 2019 and Apr 2020 are above the "expected" ones since the orbit solutions provided by ESOC are using the new ARP configuration [AD.5], whereas the CPOD products are still making use of the old one.

3.8.2. NRT

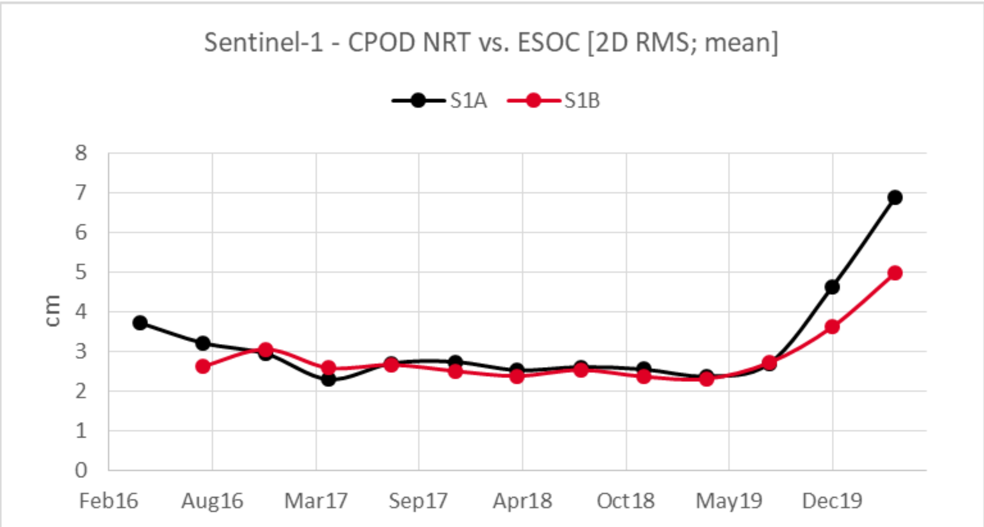

Figure 3-4: Sentinel-1 CPOD NRT vs. ESOC [2D RMS; mean] (cm)

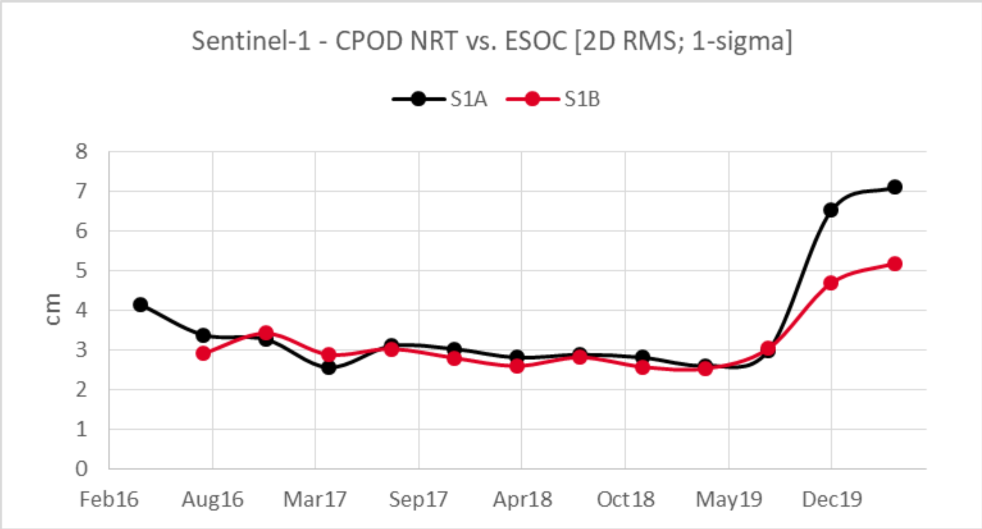

Figure 3-5: Sentinel-1 CPOD NRT vs. ESOC [2D RMS; 1-sigma] (cm)

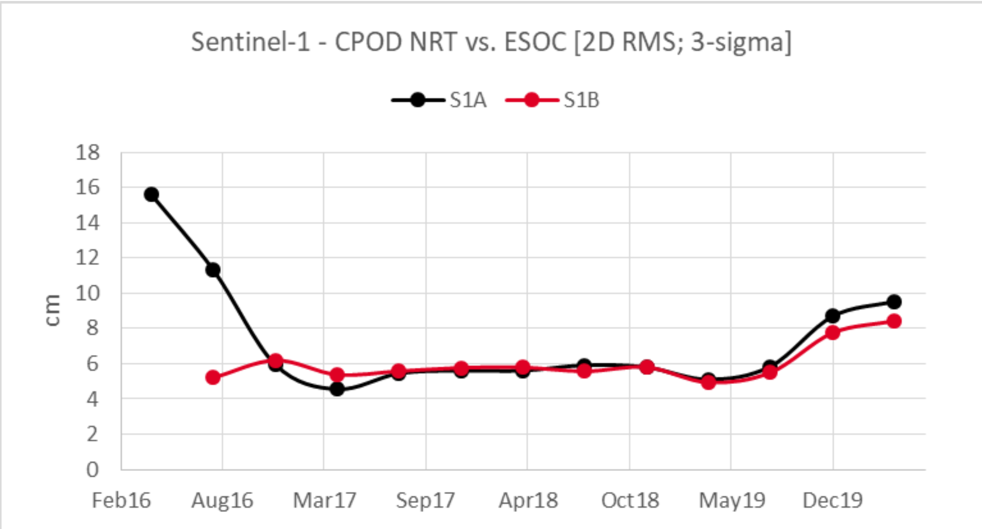

Figure 3-6: Sentinel-1 CPOD NRT vs. ESOC [2D RMS; 3-sigma] (cm)

Note: the values shown on Dec 2019 and Apr 2020 are above the ones obtained on past time periods since the orbit solutions provided by ESOC are using the new ARP configuration [AD.5], whereas the CPOD products are still making use of the old one.

3.8.3. NTC

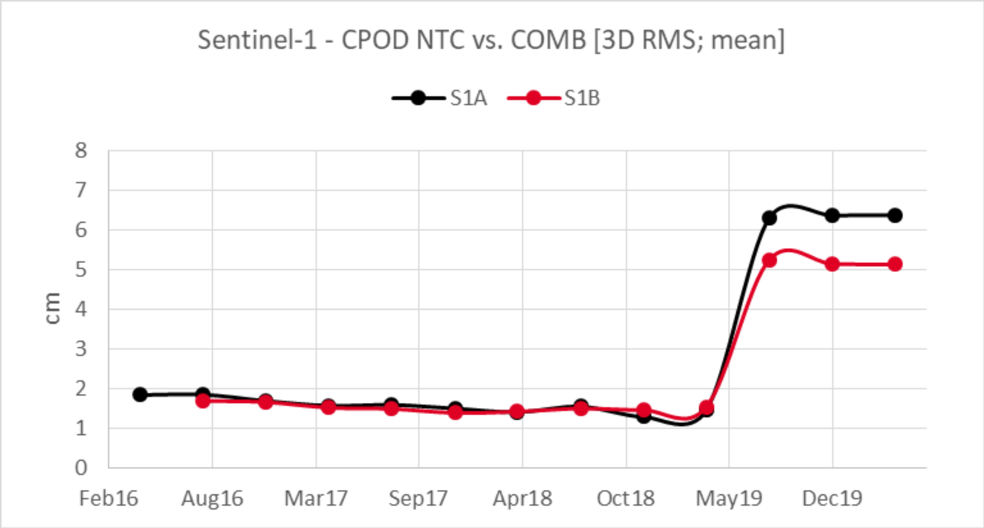

Figure 3-7: Sentinel-1 CPOD NTC vs. COMB [3D RMS; mean] (cm)

Note: The jump on NTC comparisons between period Feb-May 2019 (around 1.5 cm), Jun-Sep 2019 (around 6 cm), Oct 2019-Jan 2020 (around 6 cm), and Feb-May 2020 (around 6 cm) is due to the change of the configuration used by the CPOD QWG [AD.5], to use a new location of the GPS Antenna Reference Point (ARP). The ARP will be changed soon after an agreement with ESA.

END OF DOCUMENT