Copernicus POD Service

Copernicus POD Service – status and improvements

Presenter: Carlos Fernández (GMV)
M. Fernández (GMV), H. Peter (POSITIM),
P. Féménias (ESA/ESRIN), C. Nogueira Loddo (EUM)

2023 Ocean Surface Topography Meeting, Puerto Rico, United States
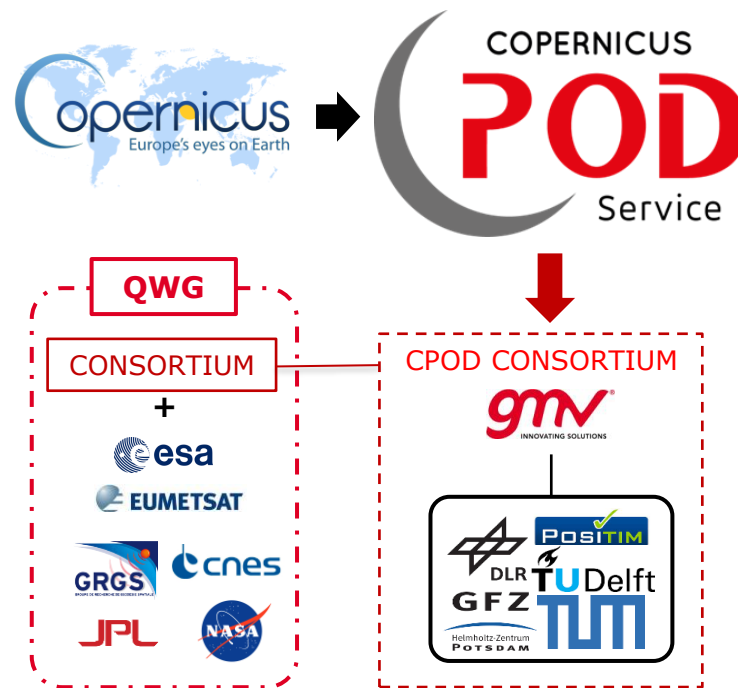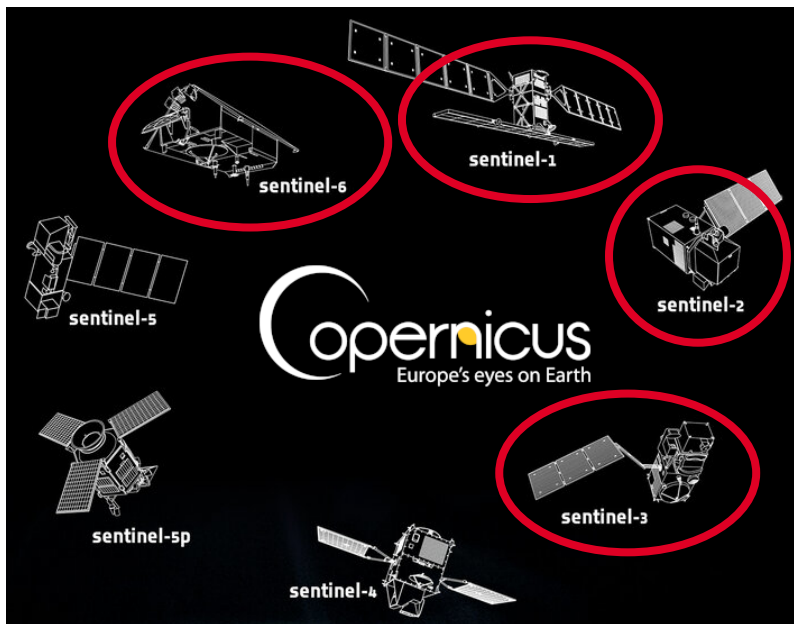
7-11 November 2023

Agenda

1. Introduction

2. Service improvements

3. Upcoming evolutions

4. Conclusions

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CPOD Service – Introduction

CPOD SERVICE

The **Copernicus POD (CPOD) Service** is responsible for the operational generation of precise orbital and auxiliary products for the Copernicus Sentinel missions.
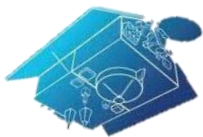
CPOD SERVICE – PRODUCTS

The CPOD Service offers operational support of **altimetry** missions: Sentinel-3 and Sentinel-6

Sentinel-3:
- CPF prediction files for ILRS
- NRT/STC/NTC orbital products
- NRT/STC/NTC platform data files
- GNSS hourly and daily RINEX files
- Quaternion files

Sentinel-6:
- NRT orbital products
- GNSS hourly and daily RINEX files
- Quaternion files

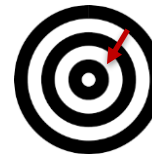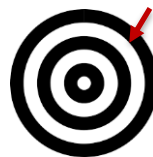| Predictions	Near-Real Time	Short-Time Critical	Non-Time Critical
< 10 min	< 10 min	< 1.5 days	< 25 days
< 1 m	< 8 cm (rad) S3 < 5 cm (rad) S6	< 3 cm (rad)	< 2 cm (rad)

CPOD SERVICE – ACTIVITIES

https://sentinels.copernicus.eu/

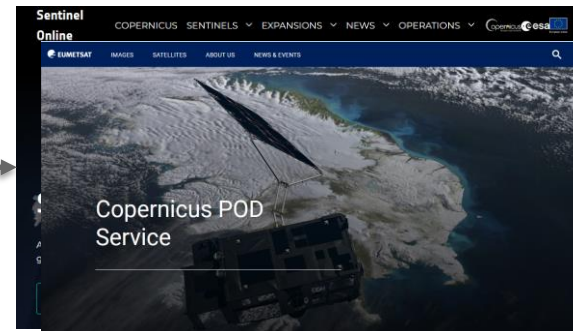https://dataspace.copernicus.eu/

CPOD SERVICE – ACTIVITIES

https://www.eumetsat.int/copernicus-pod-service

https://dataspace.copernicus.eu/
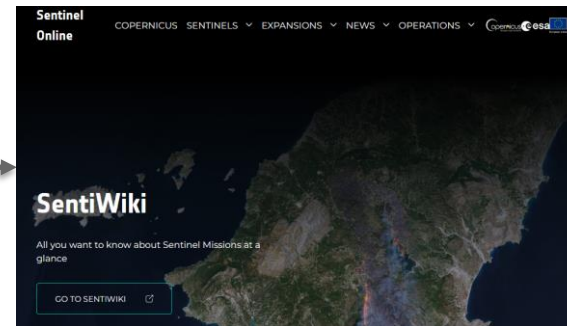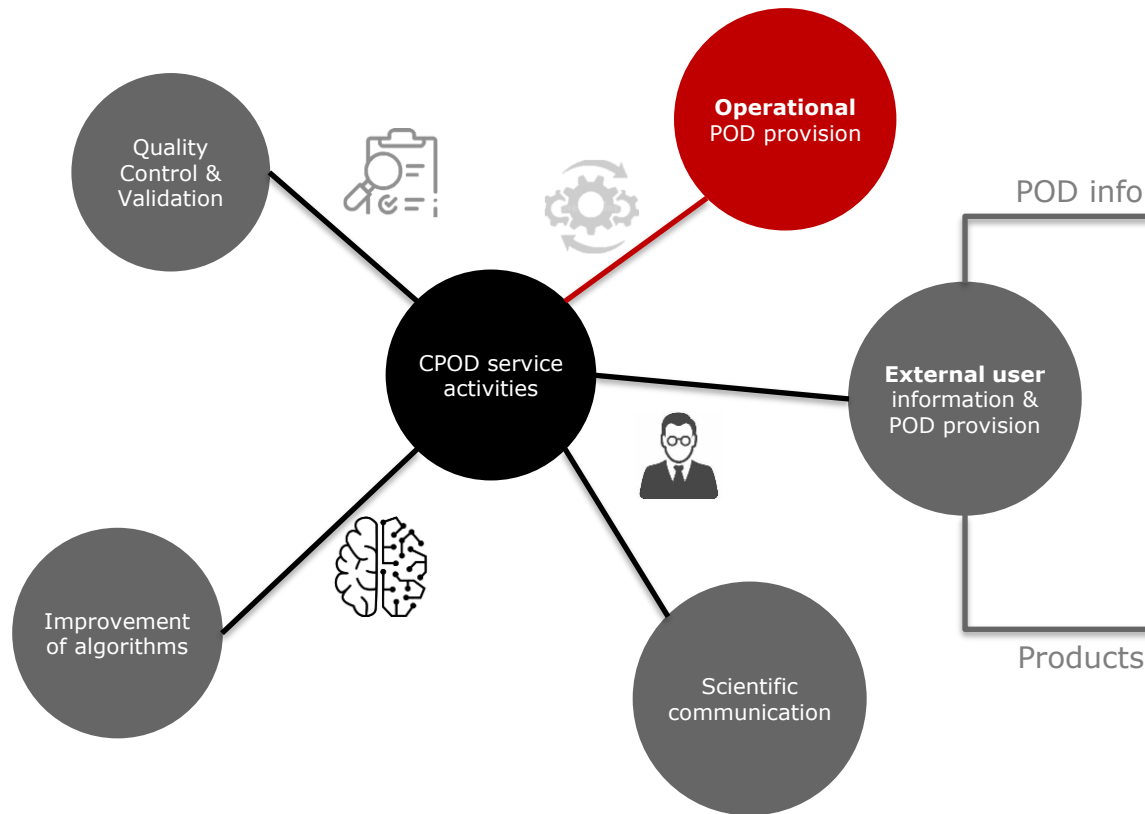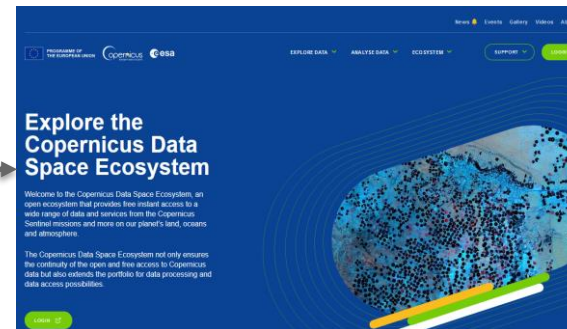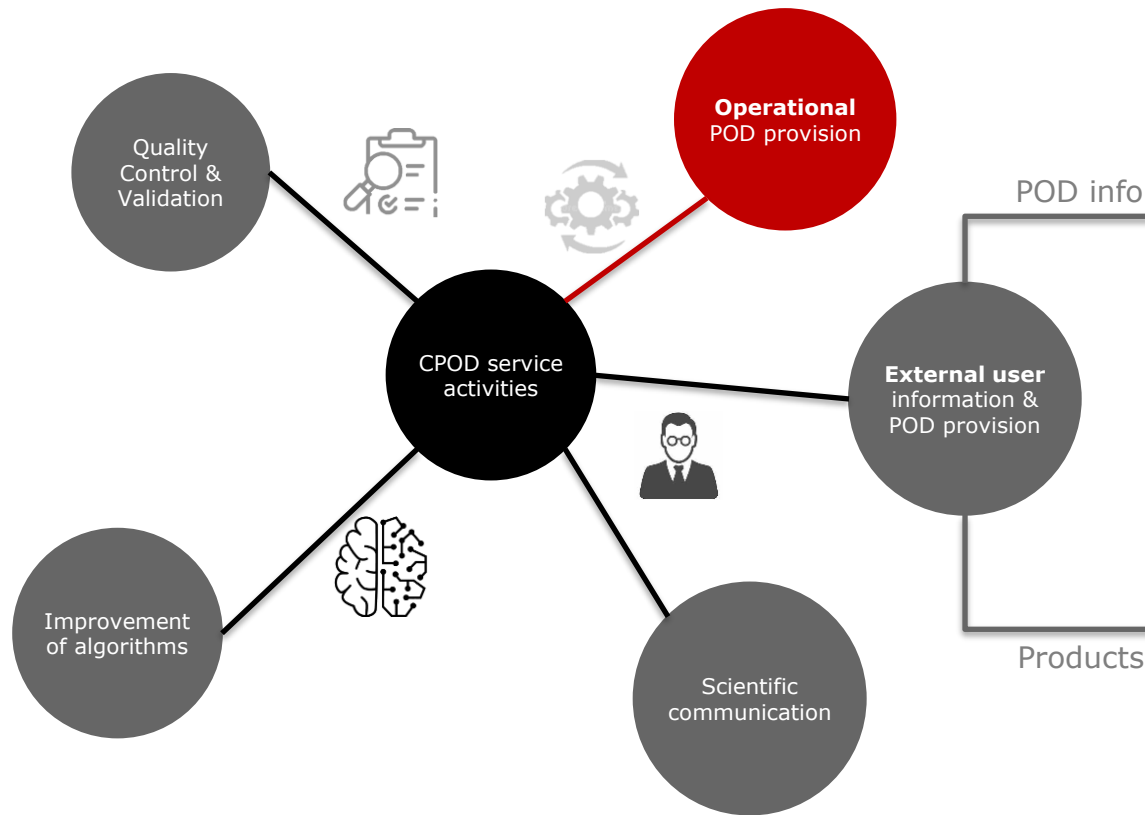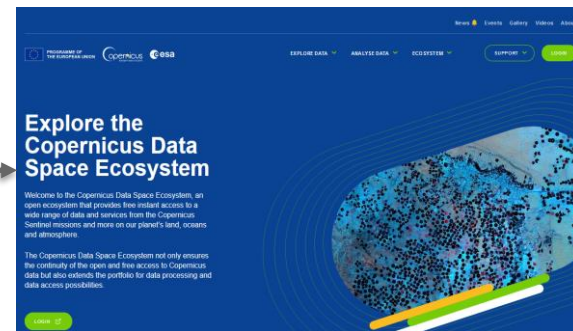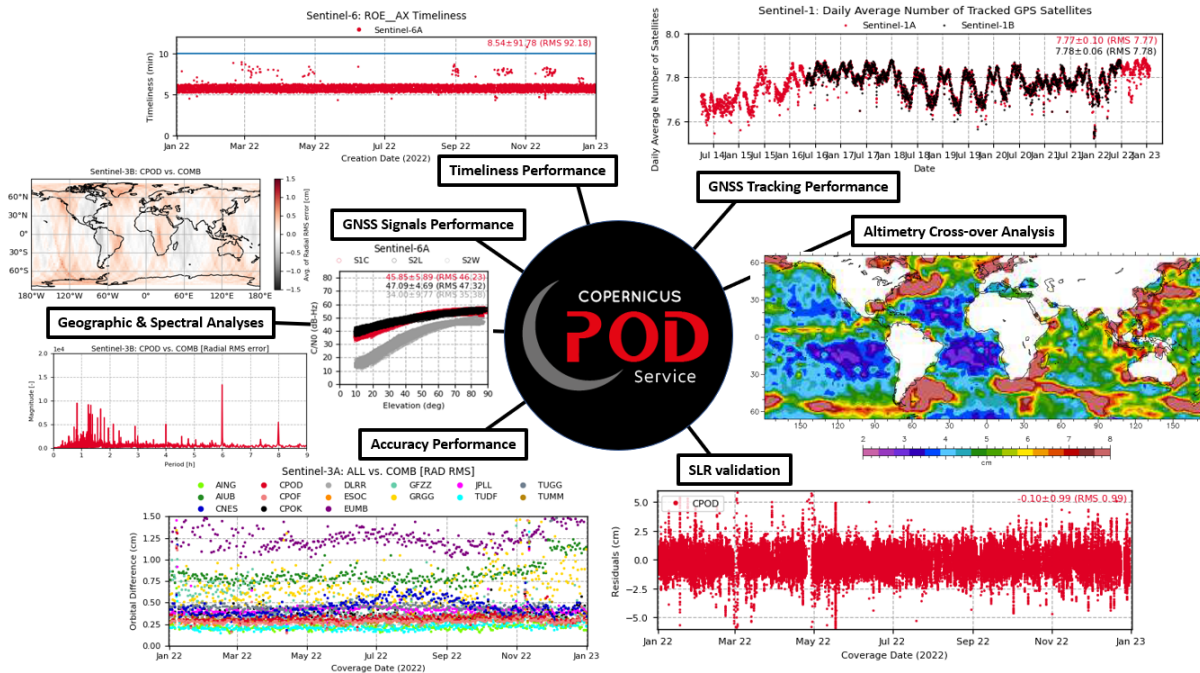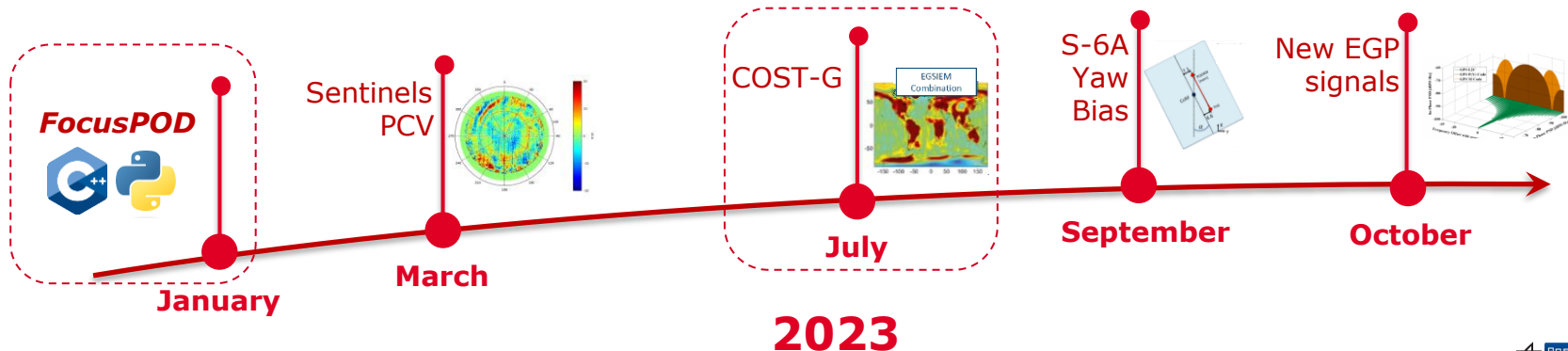
CPOD SERVICE – QC

The CPOD Service routinely performs **Quality Control** activities of all generated POD products, including the generation of a <u>combined solution</u> used as reference for accuracy control.
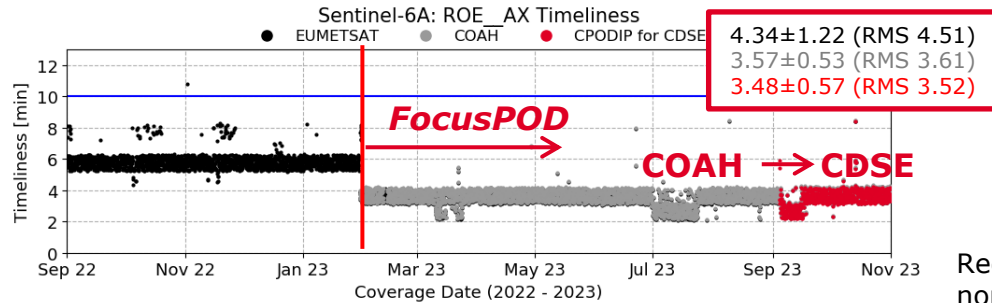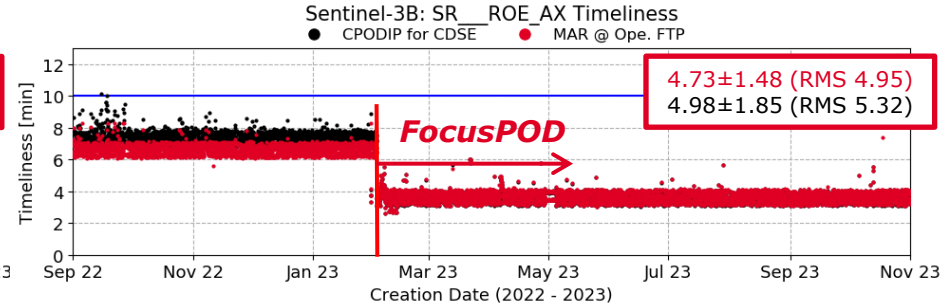
Service improvements

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SERVICE IMPROVEMENTS

- Operational transition to a new POD SW, *FocusPOD*, in Jan'23

- **Phase Centre Variation** (PCV) calibration of Sentinels antennae in ITRF20 in Mar'23

- Deploy of **COST-G** Fitted Signals Model (FSM) time-varying gravity field in Jul'23

- Application of empirical **S-6A yaw bias** to CPOD products in Sep'23

- New External GNSS Provider (EGP) **ref. signals** from GMV network of stations in Oct'23

FocusPOD

Sentinels PCV

COST-G

S-6A Yaw Bias

New EGP signals

January

March

July

September

October

2023

CPOD PERFORMANCE 2023 (I)

NRT CPOD Products: timeliness

Sentinel-3A: SR__ROE_AX Timeliness
- CPODIP for CDSE
- MAR @ Ope. FTP

4.74±1.49 (RMS 4.97)
4.99±1.86 (RMS 5.33)

FocusPOD

Sentinel-3B: SR__ROE_AX Timeliness
- CPODIP for CDSE
- MAR @ Ope. FTP

4.73±1.48 (RMS 4.95)
4.98±1.85 (RMS 5.32)

FocusPOD

Sentinel-6A: ROE__AX Timeliness
- EUMETSAT
- COAH
- CPODIP for CDSE

4.34±1.22 (RMS 4.51)
3.57±0.53 (RMS 3.61)
3.48±0.57 (RMS 3.52)
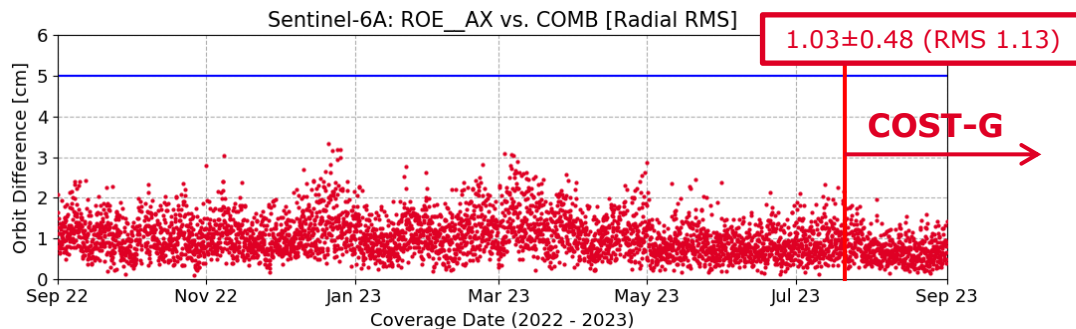
FocusPOD

COAH → CDSE
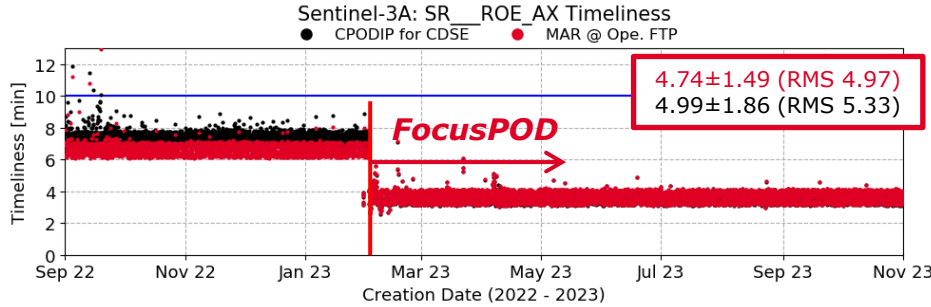
Reduced timeliness in non-eclipse regions

CPOD PERFORMANCE 2023 (II)

NRT CPOD Products: accuracy

Sentinel-3: SR_ROE__AX vs. COMB [Radial RMS]

1.36±0.73 (RMS 1.55)
1.29±0.68 (RMS 1.45)

COST-G

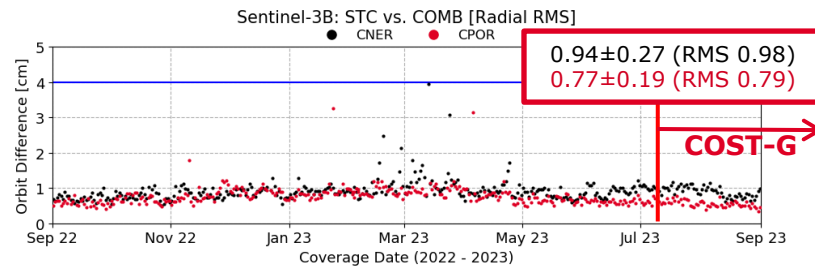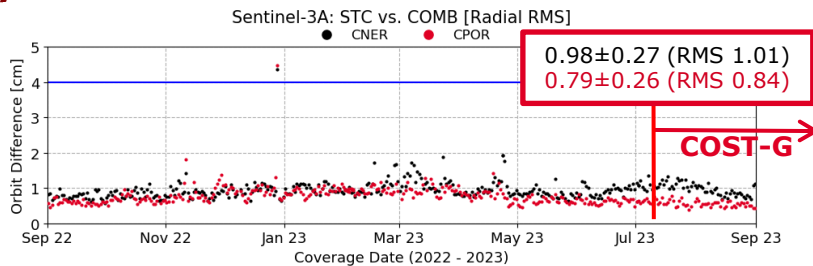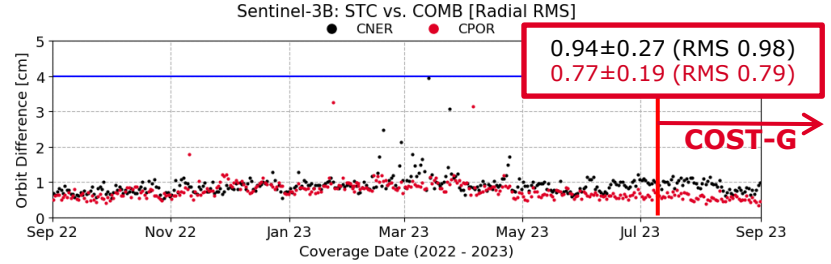Sentinel-6A: ROE__AX vs. COMB [Radial RMS]

1.03±0.48 (RMS 1.13)

COST-G

CPOD PERFORMANCE 2023 (III)

STC/NTC CNES & CPOD Products

CPOD PERFORMANCE 2023 (III)

STC/NTC CNES & CPOD Products

Sentinel-3A: STC vs. COMB [Radial RMS]
● CNER   ● CPOR

0.98±0.27 (RMS 1.01)
0.79±0.26 (RMS 0.84)

COST-G

Sentinel-3B: STC vs. COMB [Radial RMS]
● CNER   ● CPOR

0.94±0.27 (RMS 0.98)
0.77±0.19 (RMS 0.79)

COST-G

Sentinel-3A: NTC vs. COMB [Radial RMS]
● CNES   ● CPOD

0.54±0.24 (RMS 0.59)
0.35±0.24 (RMS 0.42)

COMB aligned to ITRF20

COST-G

Sentinel-3B: NTC vs. COMB [Radial RMS]
● CNES   ● CPOD

0.50±0.12 (RMS 0.51)
0.28±0.07 (RMS 0.29)

COMB aligned to ITRF20
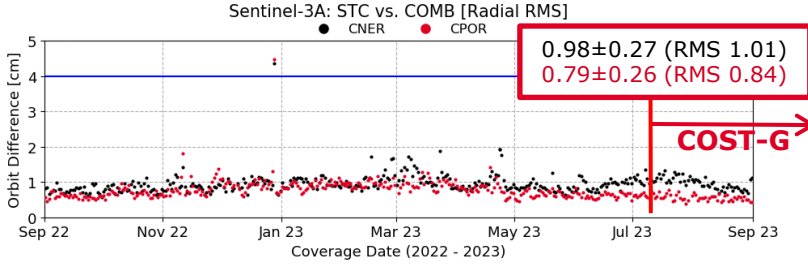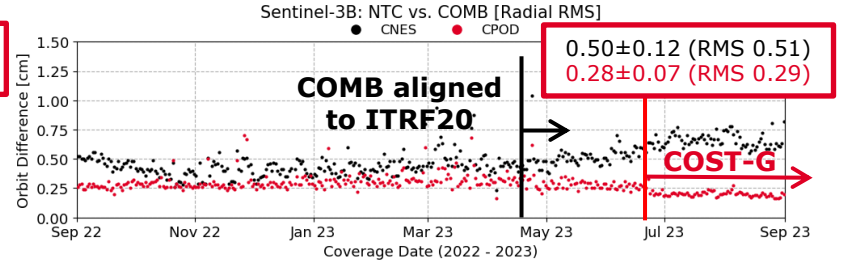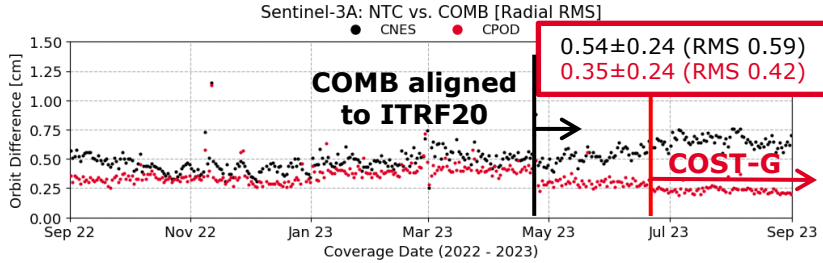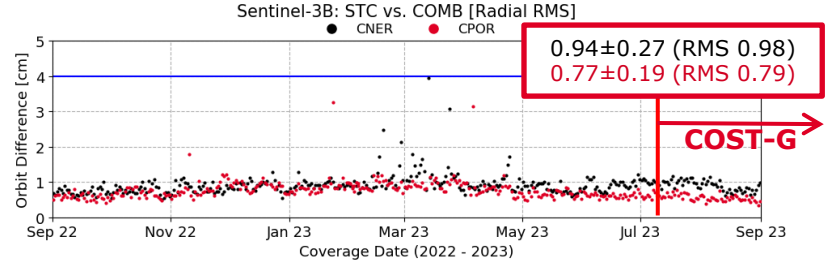
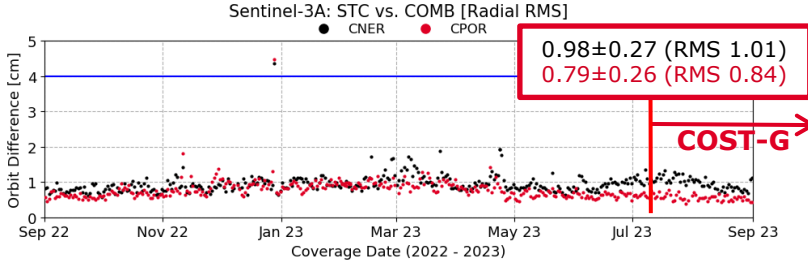COST-G

CPOD PERFORMANCE 2023 (III)

STC/NTC CNES & CPOD Products

Sentinel-3A: STC vs. COMB [Radial RMS]

0.98±0.27 (RMS 1.01)
0.79±0.26 (RMS 0.84)

Sentinel-3B: STC vs. COMB [Radial RMS]

0.94±0.27 (RMS 0.98)
0.77±0.19 (RMS 0.79)

Sentinel-3A: NTC vs. COMB [Radial RMS]

0.54±0.24 (RMS 0.59)
0.35±0.24 (RMS 0.42)

Sentinel-3B: NTC vs. COMB [Radial RMS]

0.50±0.12 (RMS 0.51)
0.28±0.07 (RMS 0.29)

CNES uses a different geocenter motion models than the rest of the CPOD QWG → orbit + **geocenter motion model** differences!!!

Upcoming evolutions

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UPCOMING EVOLUTIONS

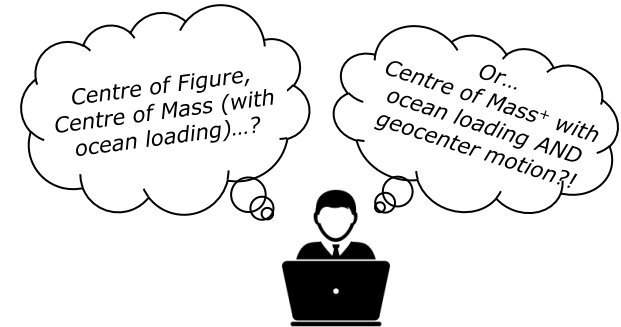- Handling of **geocenter motion model**:

#1: Quality Control

- "*How to account for different geocenter motion models when generating the combined solution?*"
- "*And when doing orbit comparisons?*"
- "*What about SLR validation?*"

#2: POD product generation

"*In what frame do users <u>need</u> the POD products?*" – application specific!!!

- Application of **Ambiguity Fixing** in STC and NRT solutions

- Possible update of **Ocean Tides** model to EOT20

Centre of Figure, Centre of Mass (with ocean loading)...?

Or... Centre of Mass⁺ with ocean loading AND geocenter motion?!

GEOCENTER MOTION (I)

- **Geocenter motion**: Motion of the center-of-mass (CoM) w.r.t. center-of-figure (CoF) – center-of-network (CoN) in practice

Wu et al. (2012)
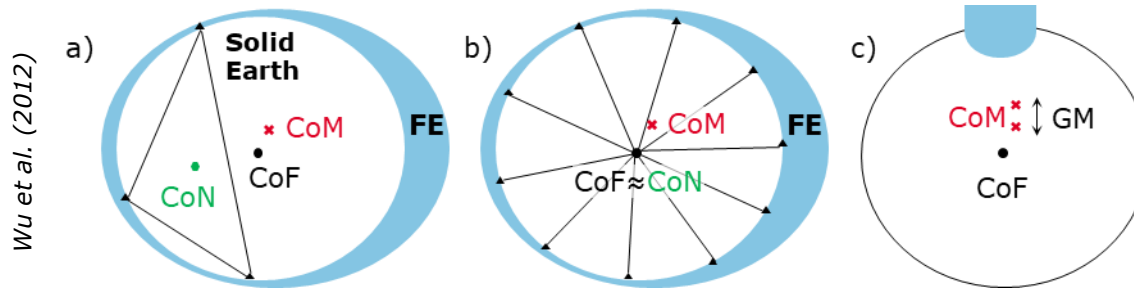
- ITRF realises CoN, but satellites orbit around the CoM!

- ITRF20 proposes an <u>official geocenter motion (GM) model</u> to account for this effect, with annual and semi-annual signals of amplitude of ~ ±4 mm

> Upcoming TN with literature review & impact on CPOD
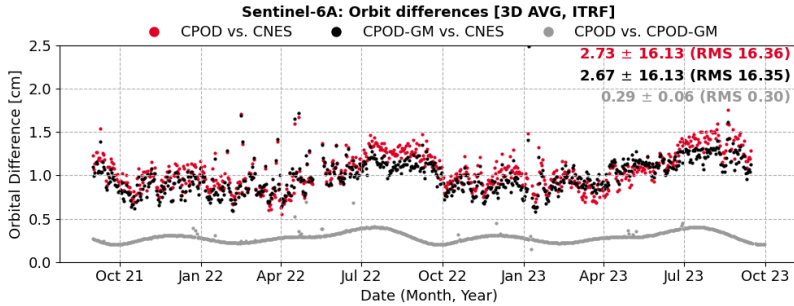
GEOCENTER MOTION (II)

- Modelling effects to realise the Geocenter motion:
  - Solid Earth tides, including permanent deformation
  - Pole Tides
  - Ocean loading CMC (FES2014b)
  - **Seasonal geocenter motion (SGM) → ITRF2020**

- The **CPOD Service** has implemented ITRF2020 SGM model → Validation:
  - Orbit comparisons against CPOD and CNES
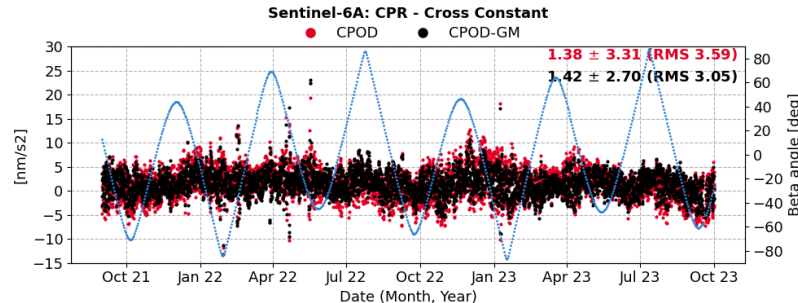 - Analysis of the processing metrics
  - SLR validation

⚠️ **CPOD-GM:** CPOD + SGM applied to GNSS input orbits (CoN) in LEO POD and to station coordinates in SLR validation

GEOCENTER MOTION: QC (I)

- **CPOD-GM** comparisons vs. CNES are <u>slightly better</u> than old CPOD's, and evolution is <u>flatter</u>
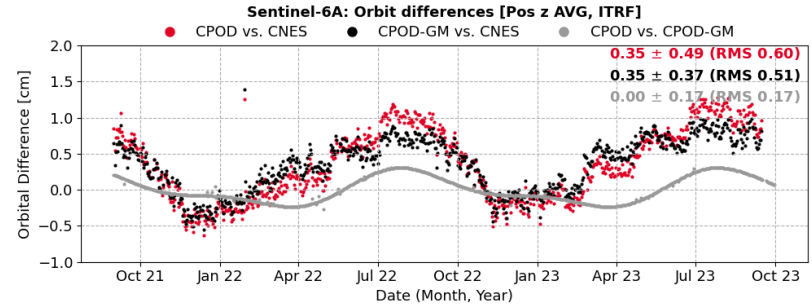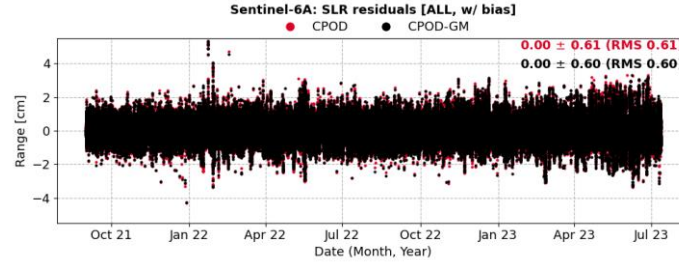

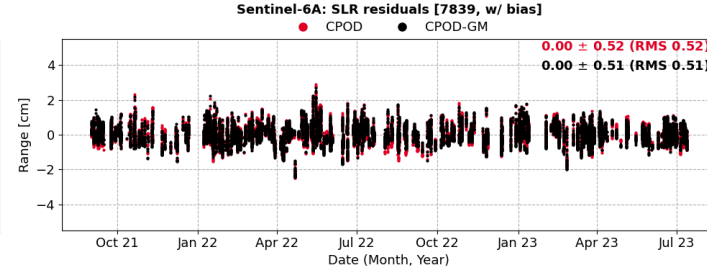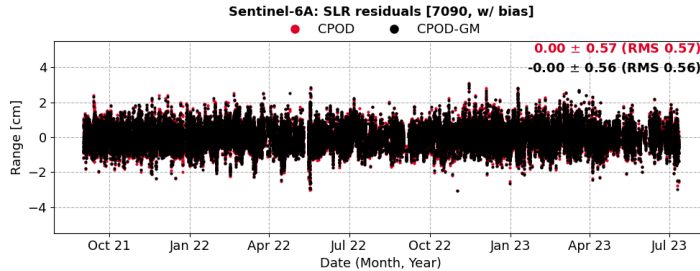- Estimated constant empirical acceleration (CPR) in cross-track direction is <u>less scattered</u>
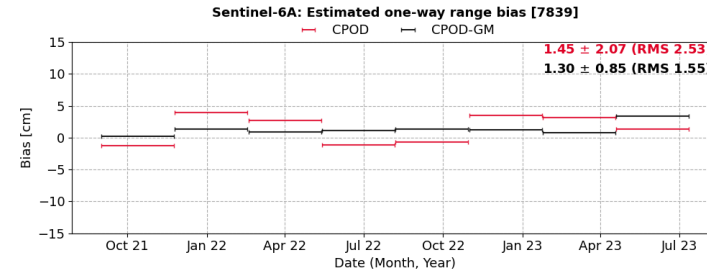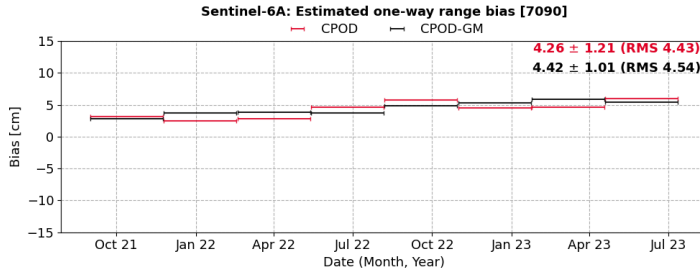
GEOCENTER MOTION: QC (II)

ALL "core" stations SLR residuals

Sentinel-6A: SLR residuals [ALL, w/ bias]
● CPOD ● CPOD-GM
0.00 ± 0.61 (RMS 0.61)
0.00 ± 0.60 (RMS 0.60)

Per station residuals

Sentinel-6A: SLR residuals [7090, w/ bias]
● CPOD ● CPOD-GM
0.00 ± 0.57 (RMS 0.57)
-0.00 ± 0.56 (RMS 0.56)

Sentinel-6A: SLR residuals [7839, w/ bias]
● CPOD ● CPOD-GM
0.00 ± 0.52 (RMS 0.52)
0.00 ± 0.51 (RMS 0.51)

Flatter range biases

Sentinel-6A: Estimated one-way range bias [7090]
CPOD CPOD-GM
4.26 ± 1.21 (RMS 4.43)
4.42 ± 1.01 (RMS 4.54)

Sentinel-6A: Estimated one-way range bias [7839]
CPOD CPOD-GM
1.45 ± 2.07 (RMS 2.53)
1.30 ± 0.85 (RMS 1.55)

GEOCENTER MOTION: WHAT NEXT?

- The CPOD Service is under discussions within the CPOD QWG to decide the way QC analyses should be performed

- Altimetry users should confirm whether they prefer orbits in **CoN or CoM**

Combined orbit solution   QWG orbits   Orbit comparisons   SLR validation

CoN or CoM?
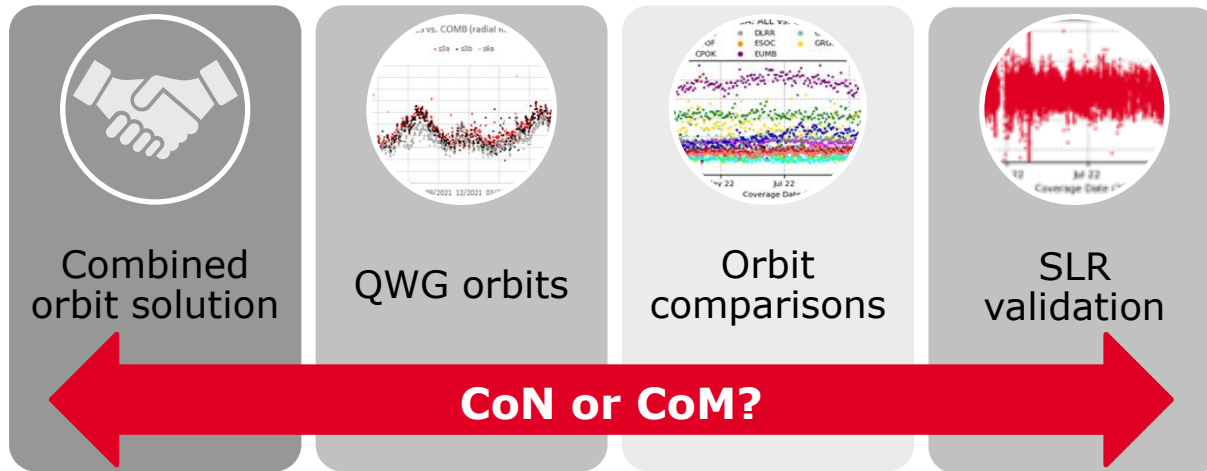
Conclusions

CONCLUSIONS

- The CPOD Service has improved the performance of the POD products, both in timeliness and accuracy, thanks to the new SW, *FocusPOD*, and the use of state-of-the-art models

- The CPOD Service is committed to keeping pushing for better performance

- The current level of accuracy between the CPOD QWG solutions allows to observe subtle effects such as the **geocenter motion modelling**, which is identified as the main topic to address in the upcoming future

<p style="text-align: center; color: red;">This needs POD requirements from (altimetry) users!!</p>

Thank you

Copernicus POD Service

Carlos Fernández (GMV)
Marc Fernández (GMV)
Heike Peter (POSITIM)
Pierre Féménias (ESA/ESRIN)
Carolina Nogueira Loddo (EUMETSAT)

S3/S6 accuracy results
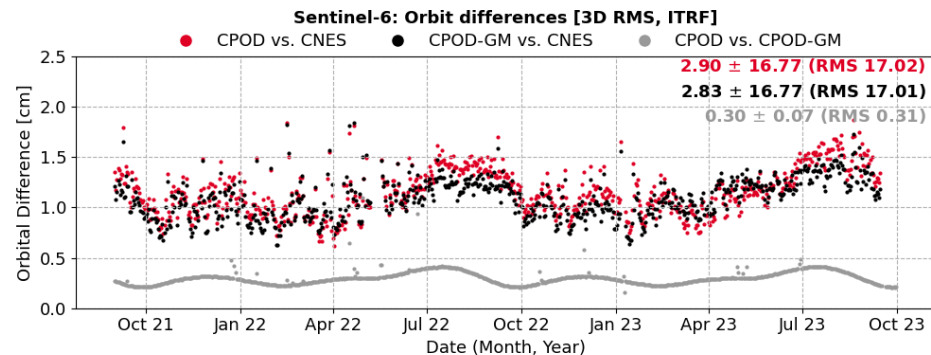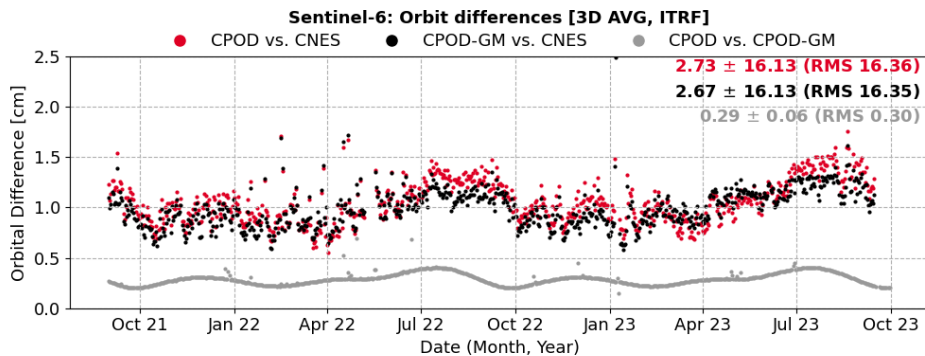
Orbit comparisons against COMB 2021-2022
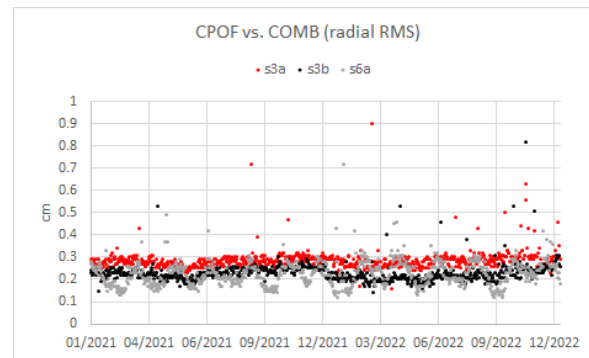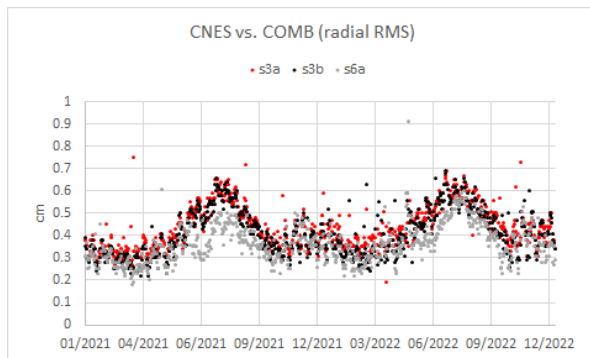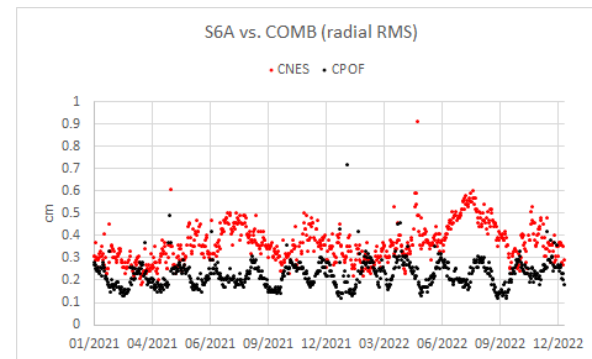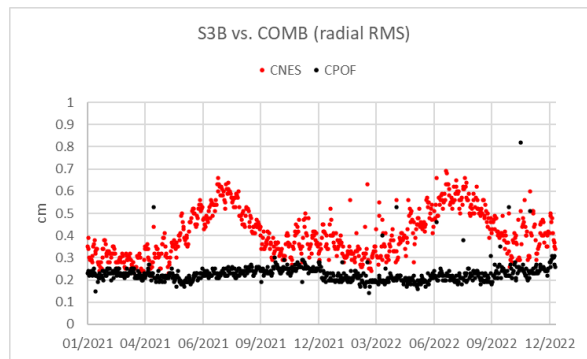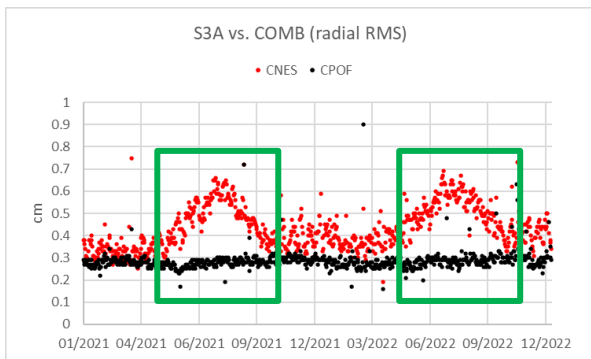
CNES: operational POE orbits
CPOF: CPOD solutions re-computed with COST-G (not operational yet); similar (slightly worse) results with operational solution
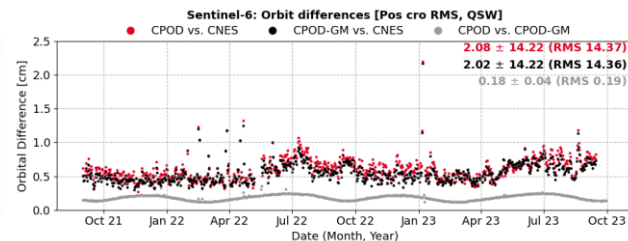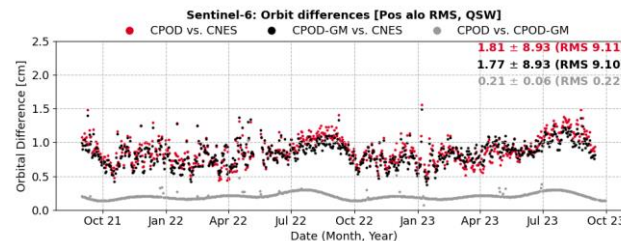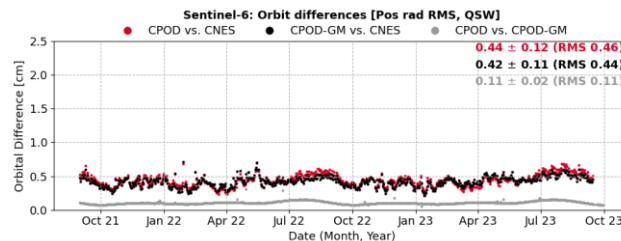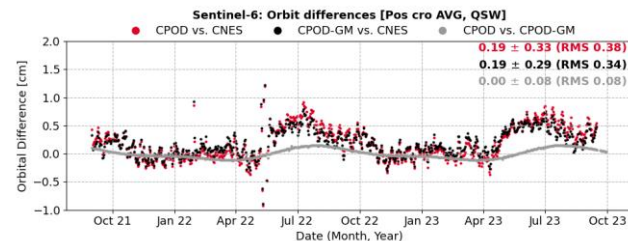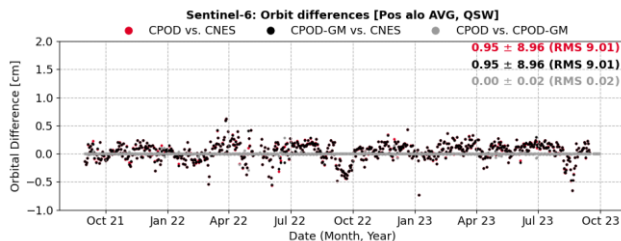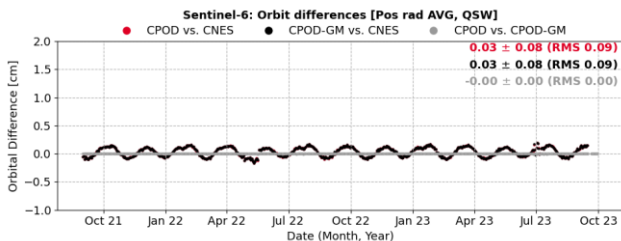
1. Orbit comparisons

- **S-6A 3D**

Sentinel-6: Orbit differences [3D AVG, ITRF]

- CPOD vs. CNES   ● CPOD-GM vs. CNES   ● CPOD vs. CPOD-GM

2.73 ± 16.13 (RMS 16.36)
2.67 ± 16.13 (RMS 16.35)
0.29 ± 0.06 (RMS 0.30)

Sentinel-6: Orbit differences [3D RMS, ITRF]

- CPOD vs. CNES   ● CPOD-GM vs. CNES   ● CPOD vs. CPOD-GM

2.90 ± 16.77 (RMS 17.02)
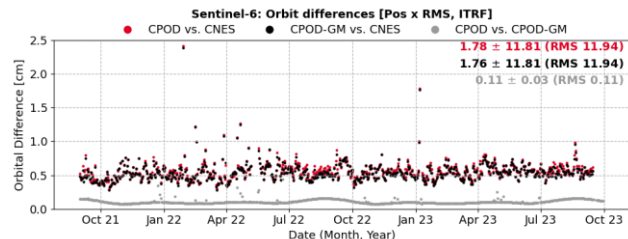2.83 ± 16.77 (RMS 17.01)
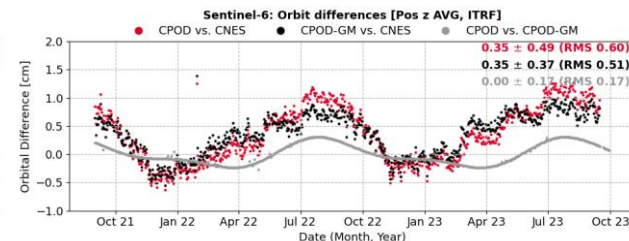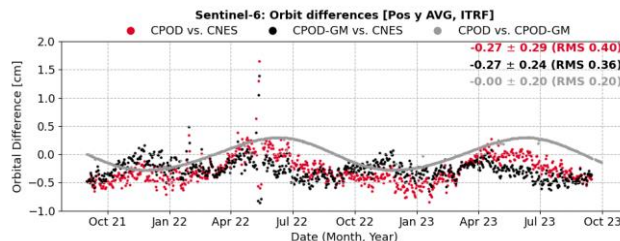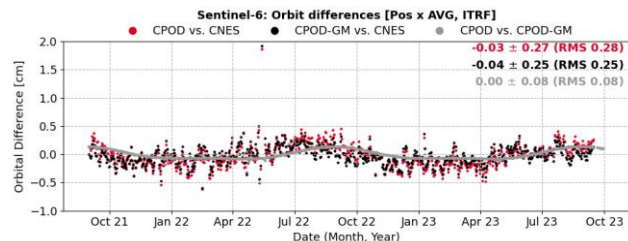0.30 ± 0.07 (RMS 0.31)

1. Orbit comparisons

- **S-6A Radial, along-track, cross-track [QSW]**

1. Orbit comparisons

- **S-6A XYZ [ITRF]**
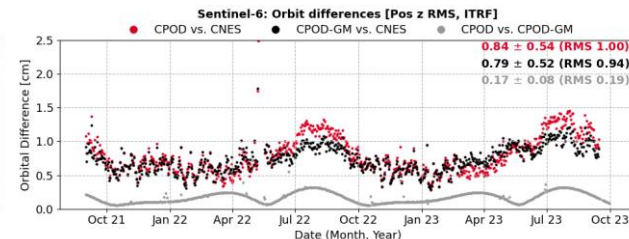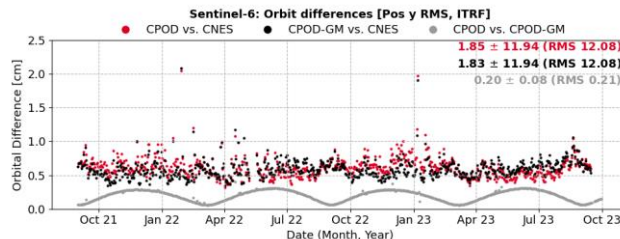
1. Orbit comparisons

- **Model comparison (2023)**