Copernicus POD Service

Improvements in the SLR processing of the Copernicus Sentinel-3 and -6 missions

2023 Virtual International Workshop on Laser Ranging
16th-20th October 2023, via Microsoft Teams

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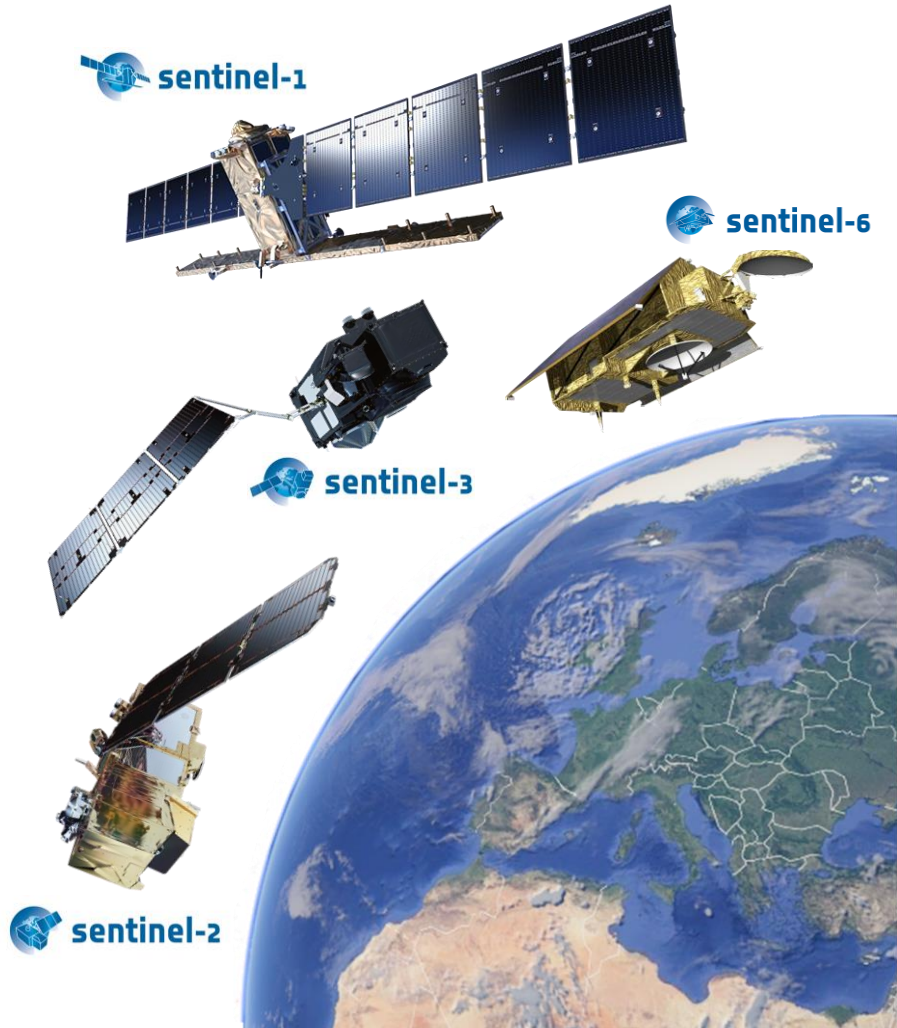


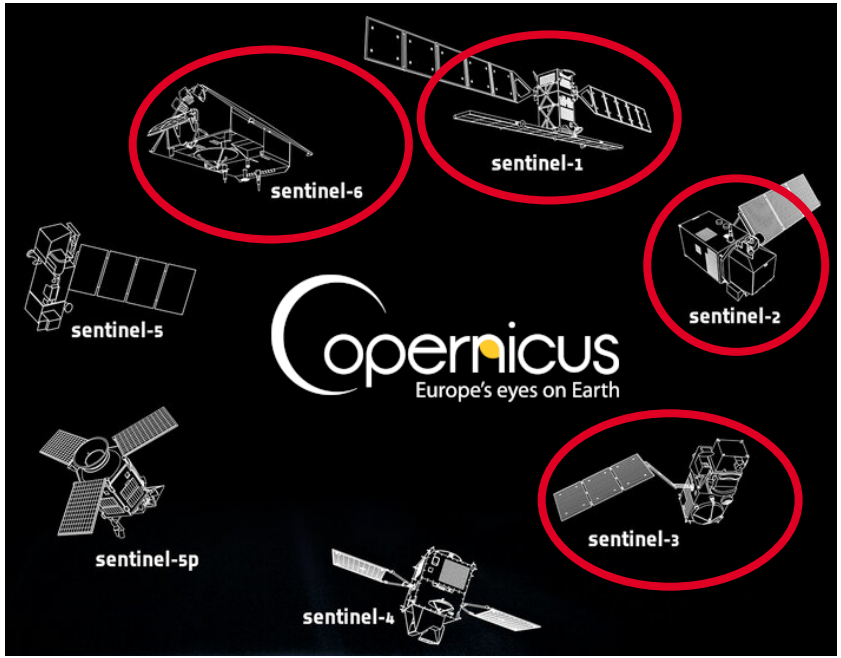
Agenda

1. Introduction
2. Mono-satellite Results
3. Multi-satellite Results
4. Conclusions

1. Introduction

1. Introduction

Copernicus POD (CPOD) Service



- From the six Sentinel families, there are four (circled in red) which require **high levels of orbit accuracy**.

CONSORTIUM

COPERNICUS POD Service

gmv INNOVATING SOLUTIONS

DLR GFZ Helmholtz-Zentrum Potsdam

PosiTIM

TU Delft

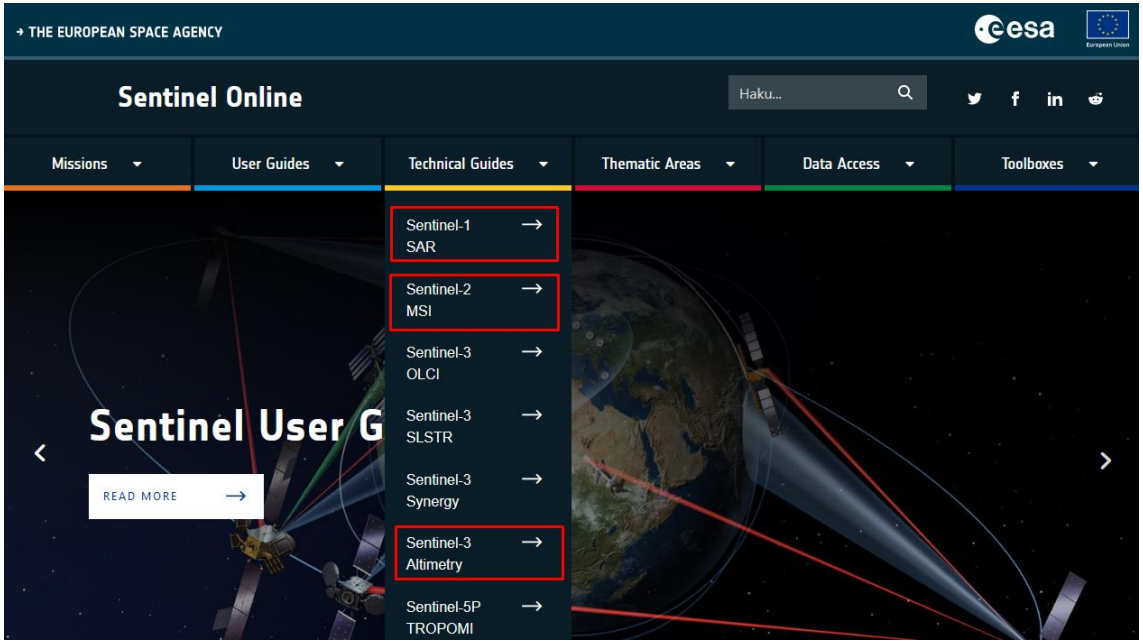
The CPOD Service is **in charge of** providing:

Orbit Products	Predicted(*), NRT, STC and NTC
Attitude Products	NRT, STC and NTC
Other auxiliary data	GNSS RINEX files, Sentinel ANTEX files, manoeuvre and mass history files…

(*) **Sentinel-3 CPF orbits** are daily delivered to the ILRS community.

1. Introduction

CPOD Service Information and Products

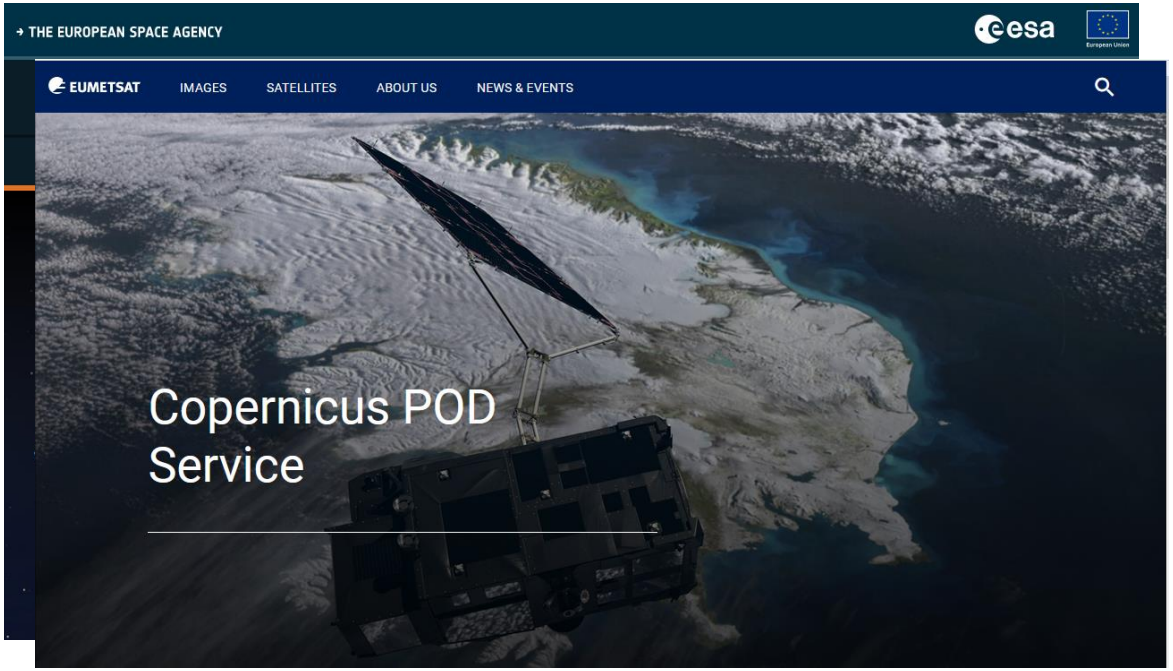


https://sentinels.copernicus.eu/

General and technical information about the CPOD Service under "Missions" and "Technical Guides" tabs in **Sentinel Online** (SoL) webpage for Sentinel-1, -2 and -3

1. Introduction

CPOD Service Information and Products



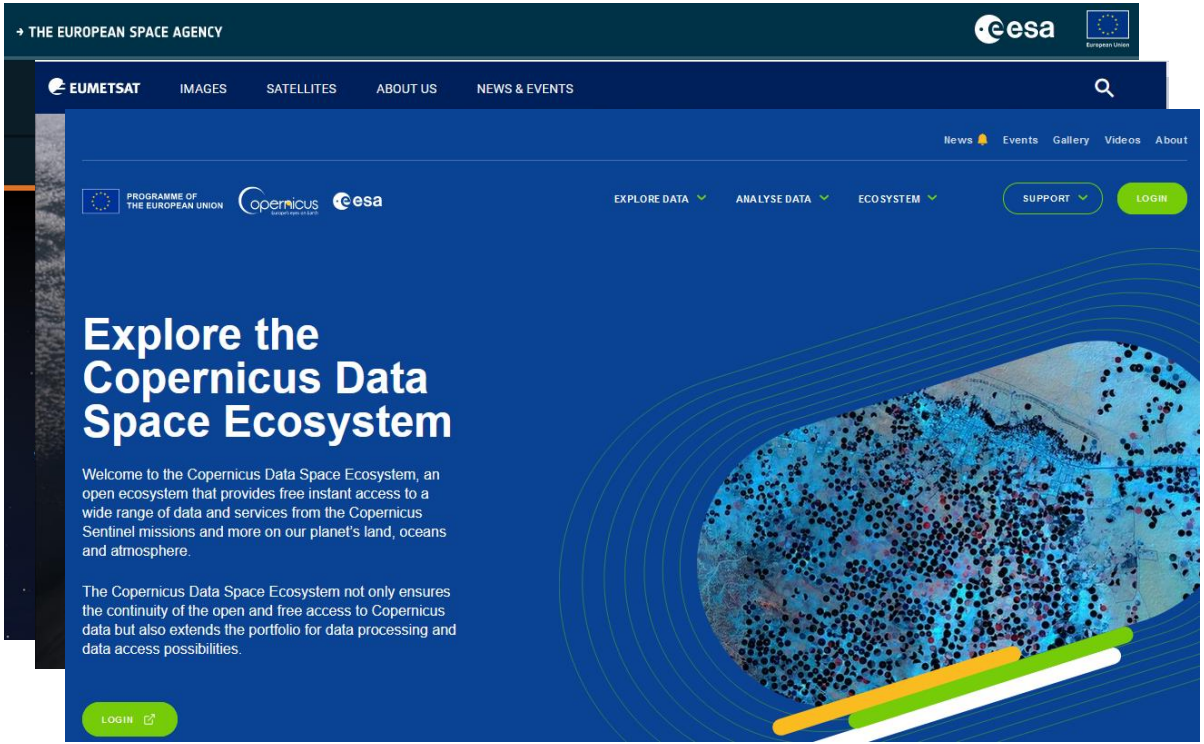
https://www.eumetsat.int/copernicus-pod-service

General and technical information about the CPOD Service under "Missions" and "Technical Guides" tabs in **Sentinel Online** (SoL) webpage for Sentinel-1, -2 and -3

General and technical information about the CPOD Service for Sentinel-6 mission in **EUMETSAT** webpage

1. Introduction

CPOD Service Information and Products



https://dataspace.copernicus.eu/

General and technical information about the CPOD Service under "Missions" and "Technical Guides" tabs in **Sentinel Online** (SoL) webpage for Sentinel-1, -2 and -3

General and technical information about the CPOD Service for Sentinel-6 mission in **EUMETSAT** webpage

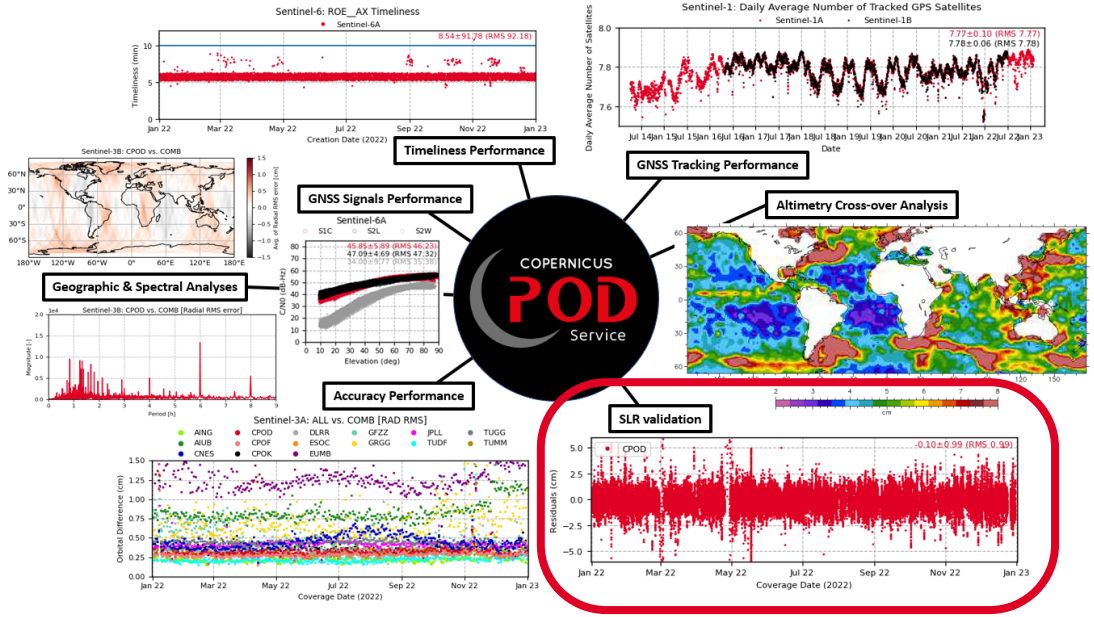
Orbit and attitude products and observation GNSS RINEX files soon available for all Sentinel's missions on the new ESA's web portal: **Copernicus Data Space Ecosystem** (CDSE)

The current web portal (Copernicus Open Access Hub) will be discontinued by the end of October!!

1. Introduction

Validation (I)

- The CPOD Service performs routine operations of validation on the products generated.
- The most complete validation is carried during the generation of **Regular Service Review** (RSR) reports (every four months) and **Yearly Service Review** (YSR) reports (every year).

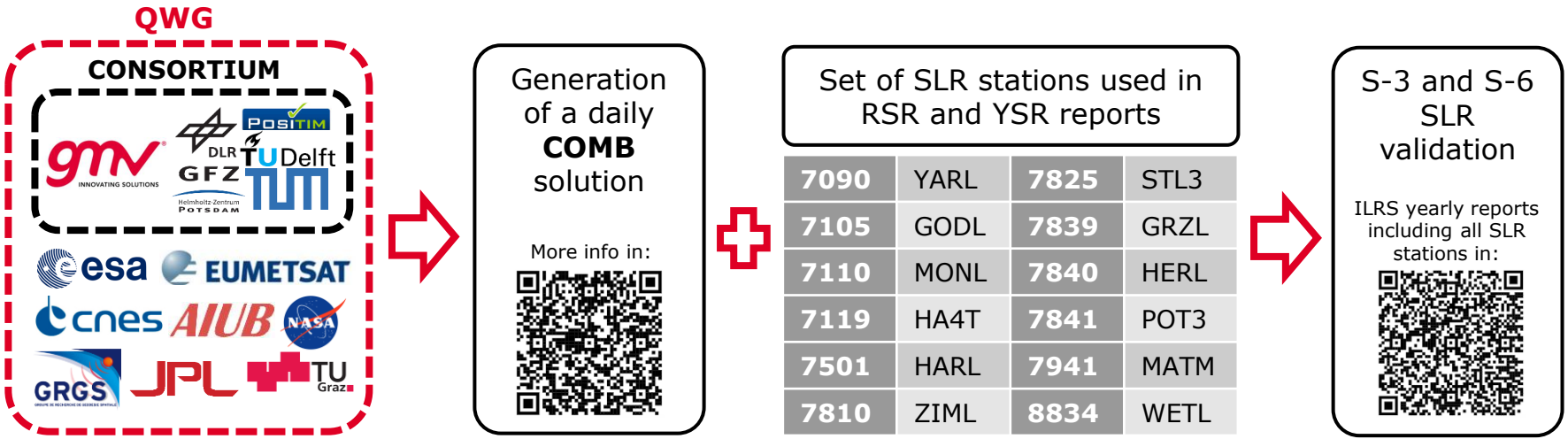


QR code to CPOD **RSR** and **YSR** reports, and other important S-3 POD documentation (within SoL webpage)

1. Introduction

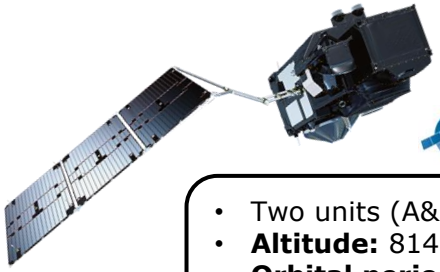
Validation (II)

- During the generation of the RSR and YSR reports, a combined orbit solution (COMB) is built from the orbits provided by the members of the **CPOD Quality Working Group** (QWG).
- The SLR validation is performed using this COMB solution, a set of SLR stations, and only for Sentinel-3 and Sentinel-6 satellites (Sentinel-1 and -2 satellites do not carry a laser retro-reflector).



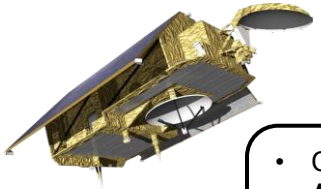
1. Introduction

Data and Models Used for the Analysis



sentinel-3

- Two units (A&B)
- **Altitude:** 814 km
- **Orbital period:** 101 min
- **Inclination:** 98.6° (polar)
- **Repeating cycle:** 27 days



sentinel-6

- One unit (A)
- **Altitude:** 1336 km
- **Orbital period:** 112 min
- **Inclination:** 66°
- **Repeating cycle:** 9.9 days

- Input data:
  - Sentinel-3 and -6 **COMB** solutions.
  - Station coordinates – SLRF2020 from ILRS.
  - LRR characterisation from "*DLR/GSOC TN 11-01 1 Issue 1.0, 2011/09/25 Range Correction for the CryoSat and GOCE Laser Retroreflector Arrays*".
- Models used:
  - 10° elevation cut-off angle.
  - Troposphere Mendes-Pavlis a-priori model.
  - Post-seismic deformation model (ITRF20).
  - No geocenter motion modelling applied yet.
- Interval of time of the analysis:
  - 72 GPS weeks: from 5th December 2021 to 22nd April 2023.
- Objective:

Evaluate the performance of the SLR validation using the data of the three satellites together in order to estimate the range biases of each SLR station and compare these values to the ones found in the Data Handling File (DHF) from the ILRS.

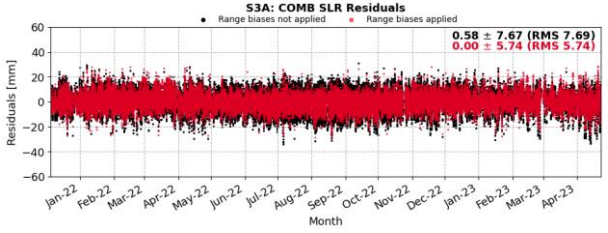
2. Mono-satellite Results

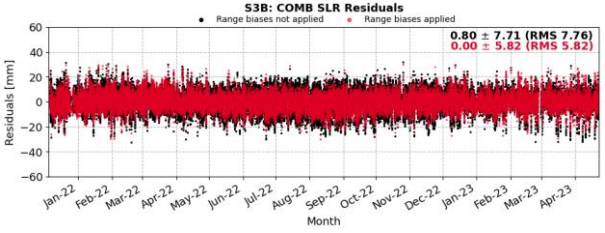
2. Mono-satellite Results

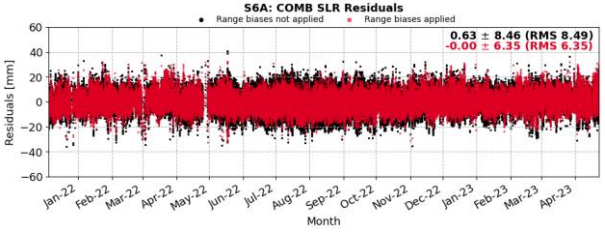
SLR Residuals [COMB, 72GPS]

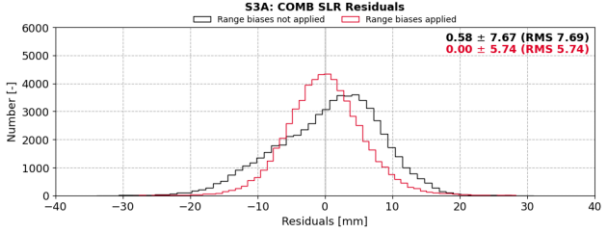
- Computed SLR residuals per Sentinel satellite for the whole period of time (72 GPS weeks).
- The statistics (mean ± STD (RMS), mm) of the obtained SLR residuals **improve** once the estimated range biases are applied.

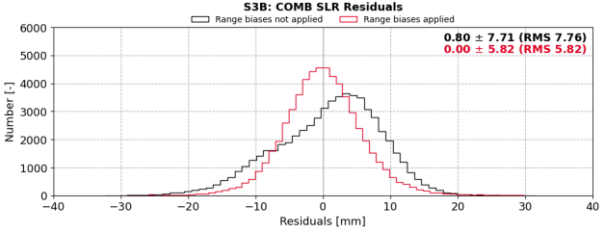
S3A	S3B	S6A

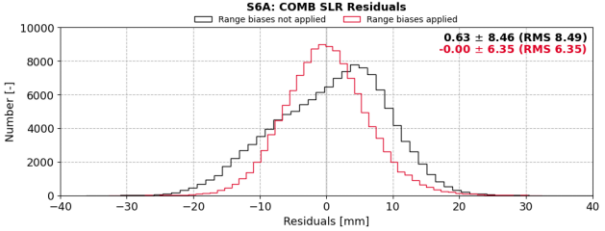








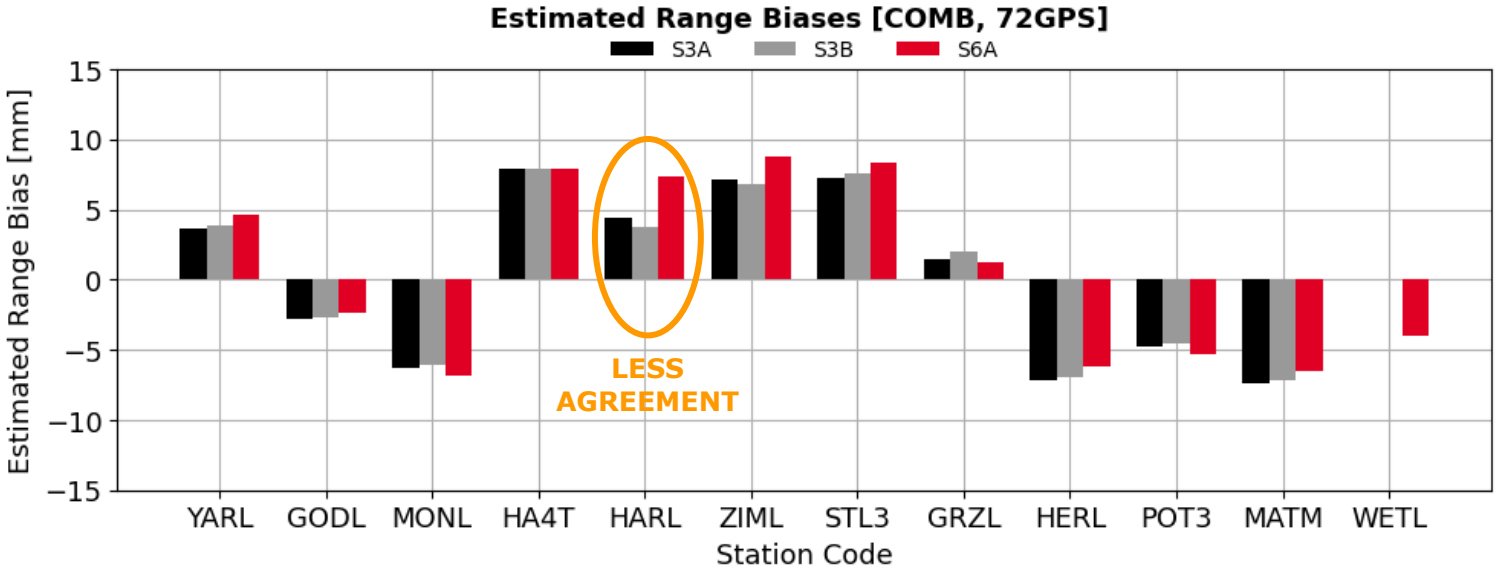




2. Mono-satellite Results

Estimated Range Biases [COMB, 72GPS]

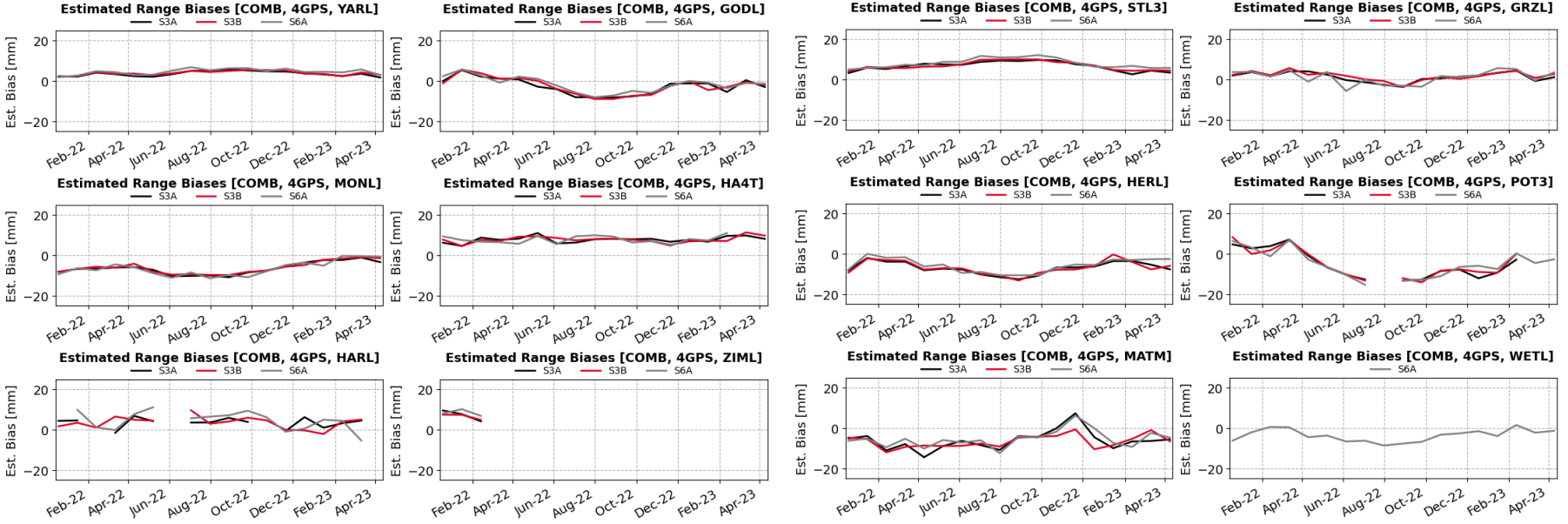
- Estimated range biases (1-way) per SLR station, obtained from the combined orbit solution and considering the estimation of one range bias per SLR station for the whole period of time.
- Overall, there is good agreement among the results obtained for each Sentinel satellite.



2. Mono-satellite Results

Estimated Range Biases [COMB, 4GPS]

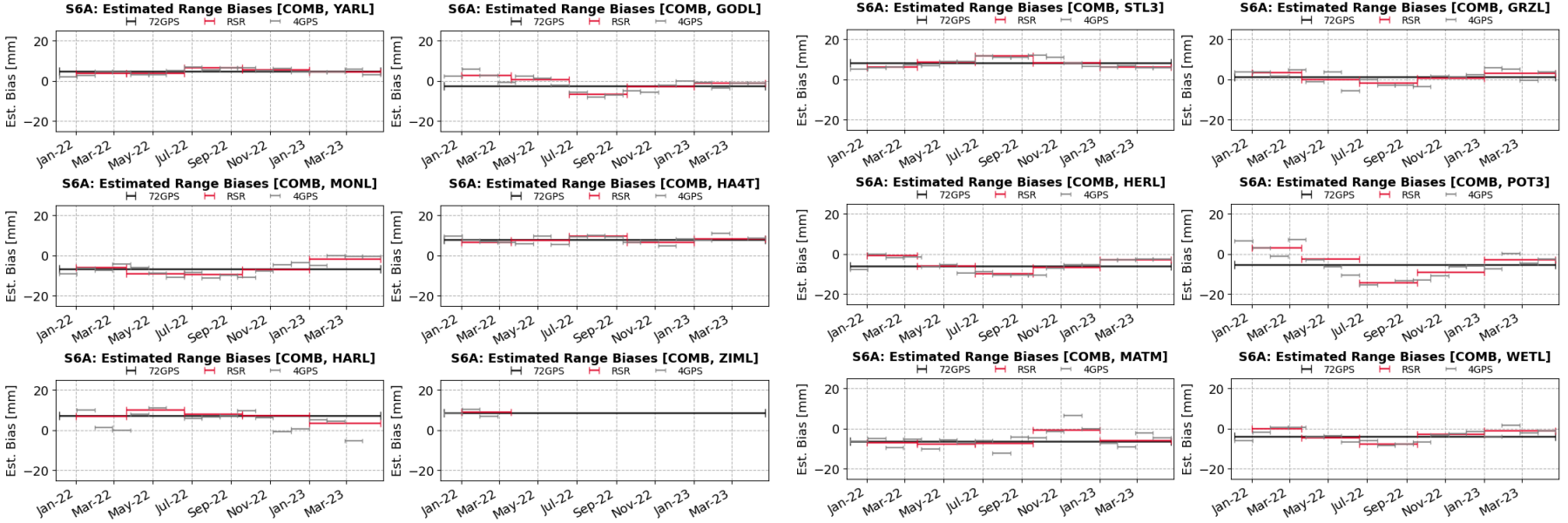
- Temporal evolution of the estimated range biases per SLR station if periods of time of 4 GPS weeks are used.
- **Similar patterns and values** are obtained for all Sentinel satellites.



2. Mono-satellite Results

Estimated Range Biases [S6A, COMB]

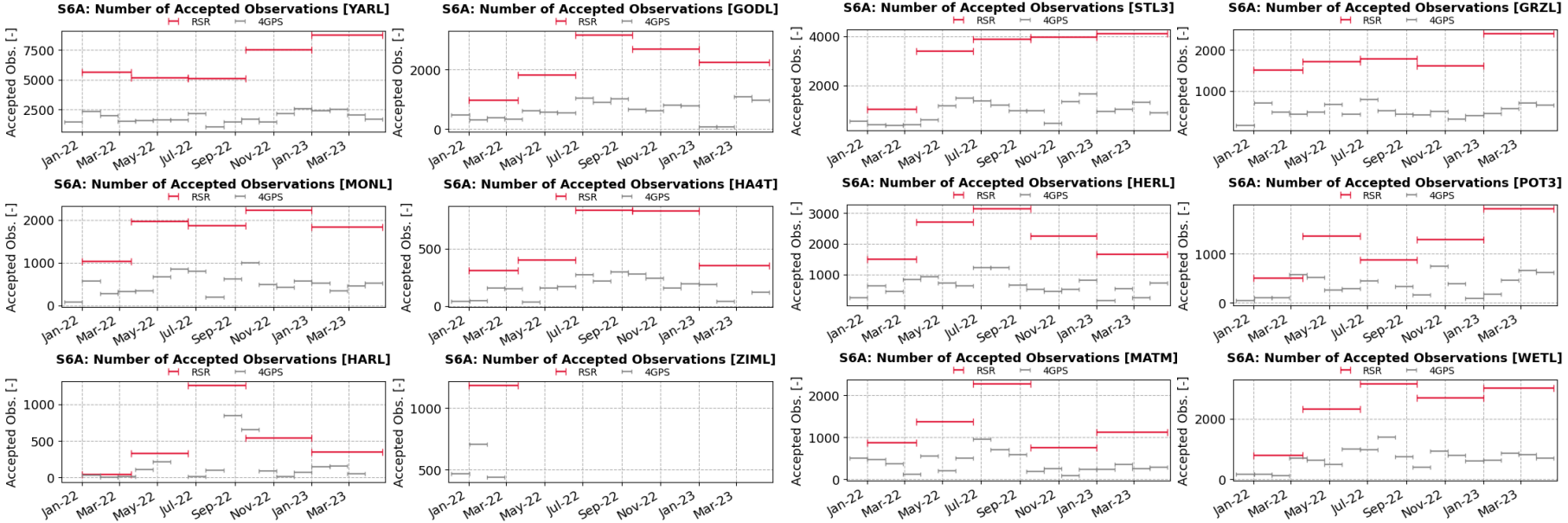
- Values of the estimated range biases per SLR station for different estimation periods of time.
- A **seasonal behaviour** is seen for most of the SLR stations.



2. Mono-satellite Results

Number of Accepted Observations [S6A, COMB]

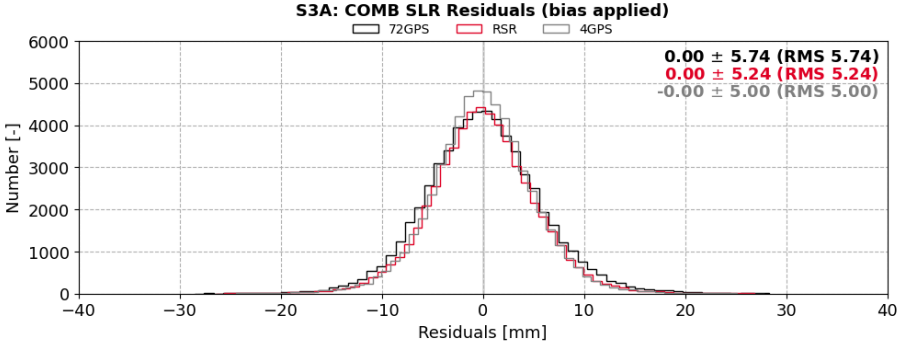
- Values of the number of accepted observations per SLR station for different estimation periods of time.
- The number of accepted observations might be a reason for the previous seasonal pattern observed.

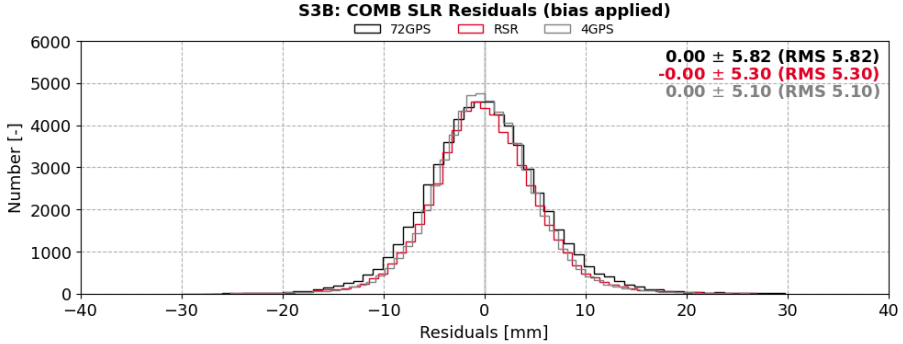


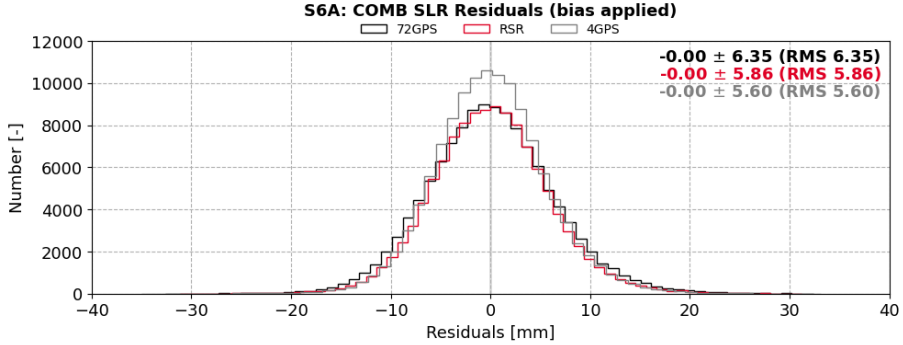
2. Mono-satellite Results

SLR Residuals [COMB]

- The obtained SLR residuals do not significantly vary when using short or large estimation periods of time.



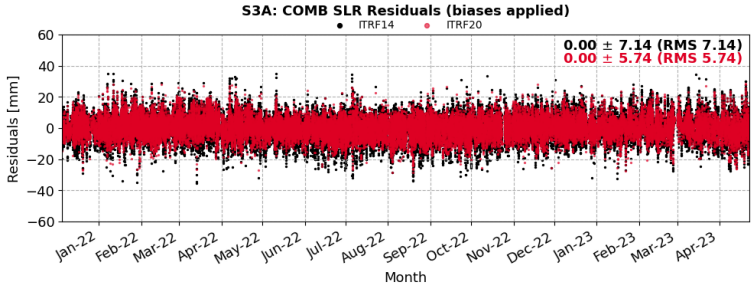


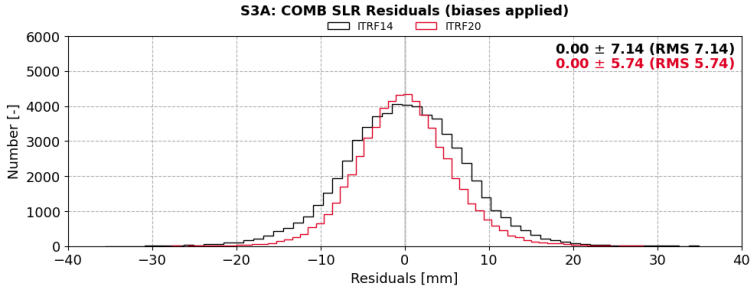


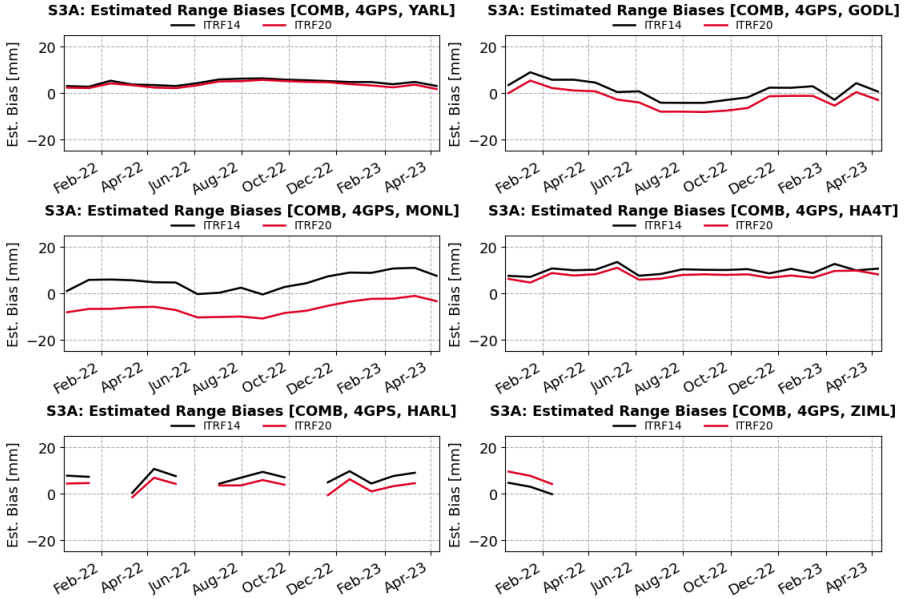
2. Mono-satellite Results

ITRF14 vs. ITRF20 [S3A, COMB]

- There is a significant **improvement** on the obtained SLR residuals when using the ITRF2020 coordinates.
- The estimated range biases between both reference systems follow a similar pattern but with a bias on the obtained values. These biases are shorter or larger depending on the SLR station.







3. Multi-satellite Results

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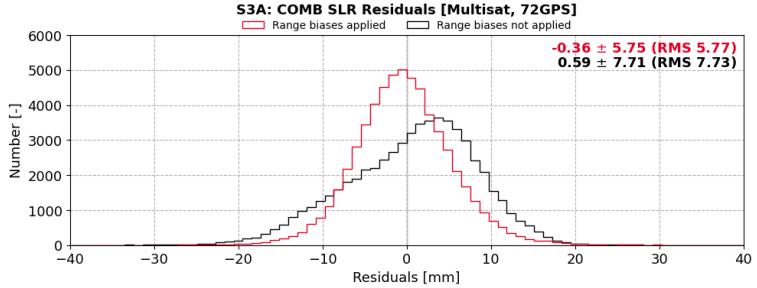
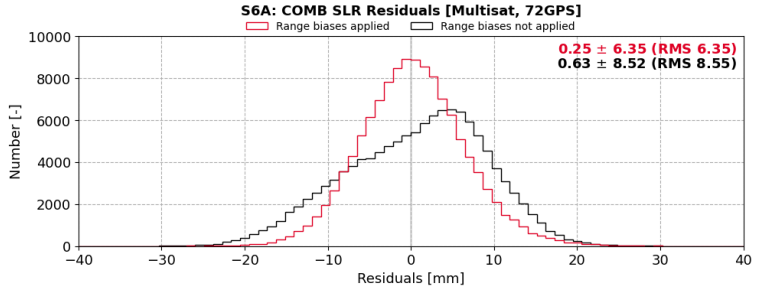
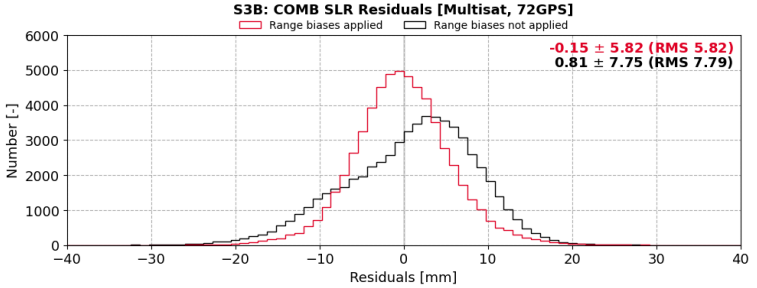
SLR Residuals [COMB, 72GPS]

- Obtained SLR residuals per Sentinel satellite if the estimated range biases are computed with data from all three Sentinel satellites during the same estimation process.
- There is a clear improvement on the SLR residuals if the estimated range biases are applied (same as mono-satellite cases), and the final computed SLR residuals are very similar to those of the mono-satellite cases.





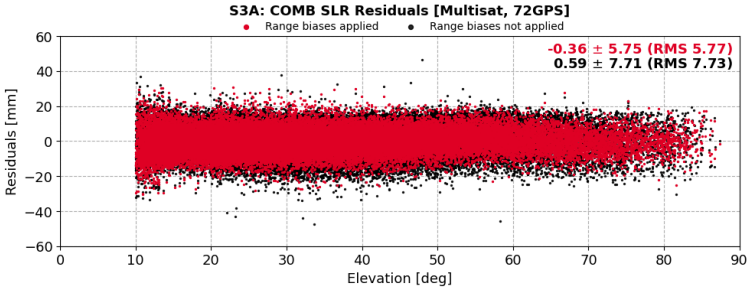


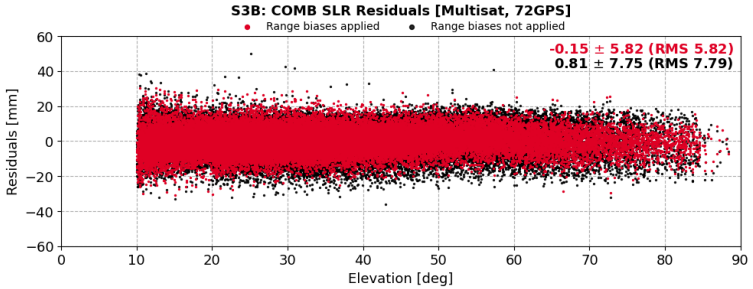
	Mono-satellite (mean±STD (RMS), mm)	Multi-satellite (mean±STD (RMS), mm)
S3A	0.00±5.74 (5.74)	-0.36±5.75 (5.77)
S3B	0.00±5.82 (5.82)	-0.15±5.82 (5.82)
S6A	0.00±6.35 (6.35)	0.25±6.35 (6.35)

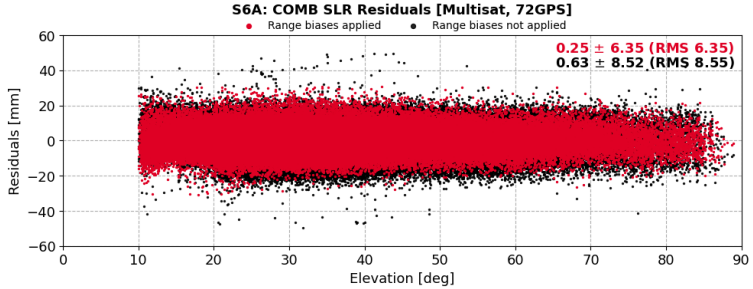
3. Multi-satellite Results

SLR Residuals per Elevation [COMB, 72GPS]

- Obtained SLR residuals per elevation angle (bear in mind that a 10° cut-off angle is used).
- At high elevations, the SLR residuals slightly show less dispersion.



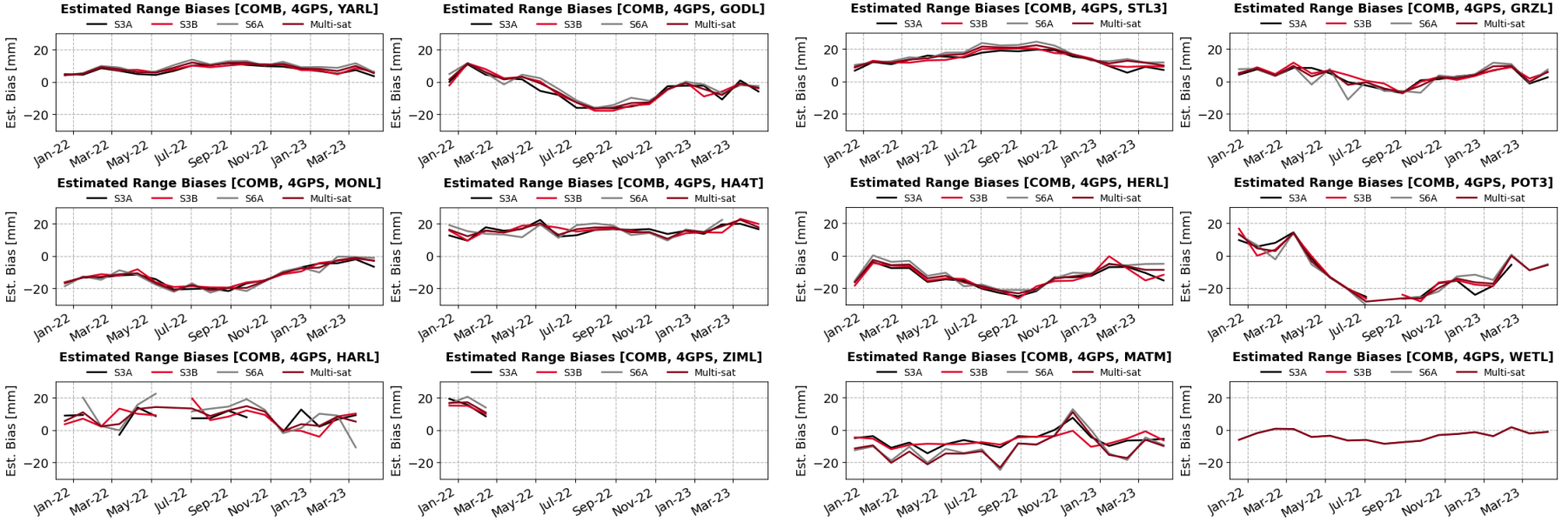




3. Multi-satellite Results

Estimated Range Biases [COMB, 4GPS]

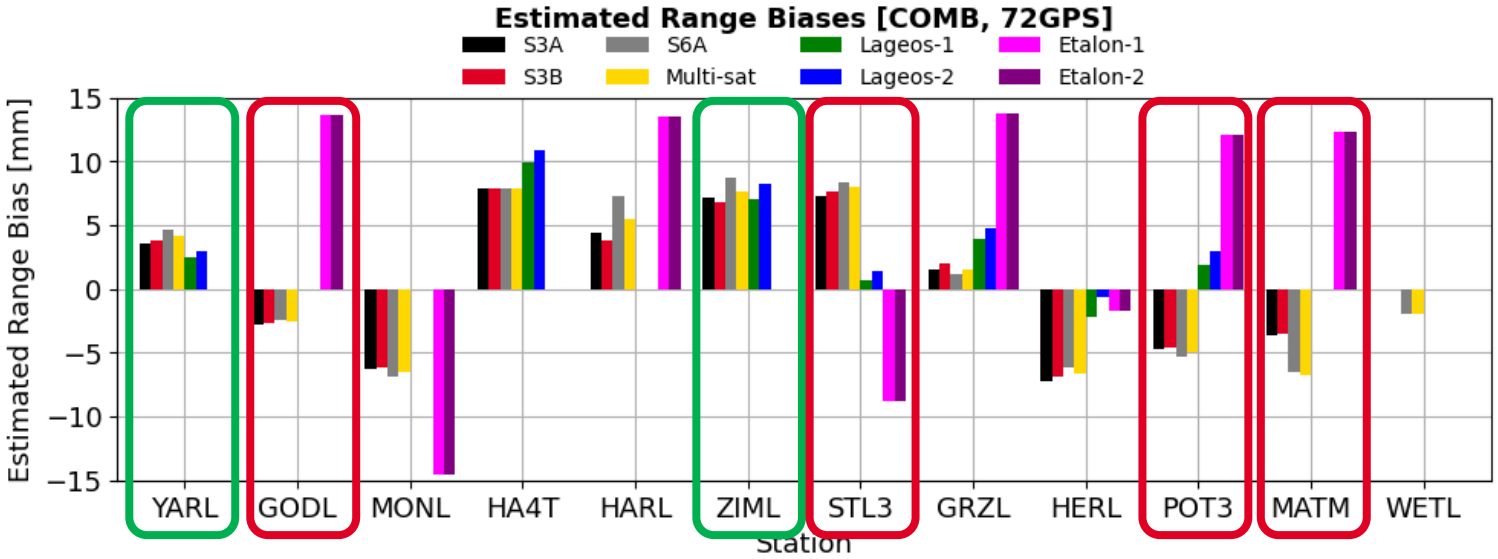
- Temporal evolution of the estimated range biases per SLR station if periods of time of 4 GPS weeks are used.
- The multi-satellite case shows **similar trends and values** as found for the mono-satellite cases.



3. Multi-satellite Results

Estimated Range Biases [COMB, 72GPS] + DHF (I)

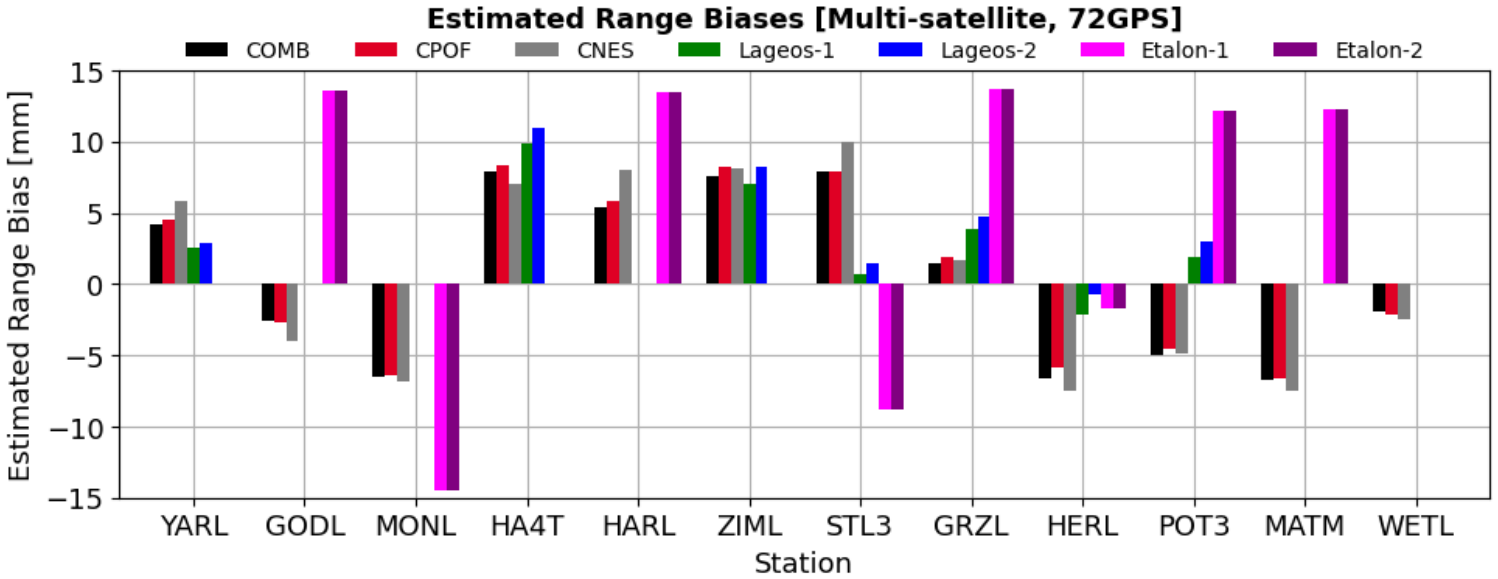
- Estimated range biases per SLR station for mono-satellite and multi-satellite cases versus the values found in the Data Handling File (DHF) provided by the ILRS for satellites: Lageos-1 and -2 and Etalon-1 and -2.
- There is good **agreement** between some SLR stations, but other SLR stations **totally disagree**.



3. Multi-satellite Results

Estimated Range Biases [COMB, 72GPS] + DHF (II)

- Estimated range biases per SLR station for other solutions than the combined solution: (a) CPOF, solution generated by the CPOD Service and used as back-up for the Sentinel-3 mission, and (b) CNES, solution provided by the *Centre National d'Études Spatiales* (operational orbits for Sentinel-3 and -6 missions).
- There are no significant discrepancies on the estimated range biases for COMB, CPOF and CNES solutions.



4. Conclusions

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Summary

- The CPOD Service is able to perform SLR validation using multiple satellites.
- The results presented within this presentation show no significant differences between the estimated range biases and computed SLR residuals from the mono-satellite and multi-satellite cases.
- The estimated values of some range biases agree with the values found in the DHF provided by the ILRS. There are other values that totally disagree.
- Further analyses, including other LEO satellites than the Sentinel satellites in the estimation process (e.g. Swarm), will be carried out by the CPOD Service.
- Processing of geodetic satellites (Lageos, Etalon) and bias estimation based on these will also be incorporated to compare directly results obtained in the DHF.
- The orbital accuracy of LEO orbits generated from SLR observations will also be checked.

Sentinel-3 and Sentinel-6 missions are very important altimetry missions that count on the invaluable support of the ILRS community.
Thank you very much for your support!

Thank you

Copernicus POD Service