GRG AC status

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IDS AWG
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Status of CNES/CLS IDS Analysis Center

❑ Status of the routine DORIS data processing

We processed DORIS data up to August 2025 (Series grg56) and provided to IDS Combination Center.

- we apply the *SAA mitigation strategy to Jason-3, Sentinel-3A, 3B, 6A and HY-2C*
- *The HY-2C and 2D solutions do not contribute to the scale determination of the multi-satellite solution*
- *we use the macromodel from Conrad et al. for Sentinel-6A*
- *we use DPOD2020 version 4.3 as the apriori model*
- Additionally, we adjust one daily normal bias (to reduce the draconitic signature, particularly on Tz, for Jason-3 and Sentinel-6A)

We also provided Sentinel3-A&B and Sentinel-6A orbits to CPOD QWG.

❑ AC studies

In progress:

Develop a strategy to mitigate the impact of increased solar activity on POD and the multi-satellite solution

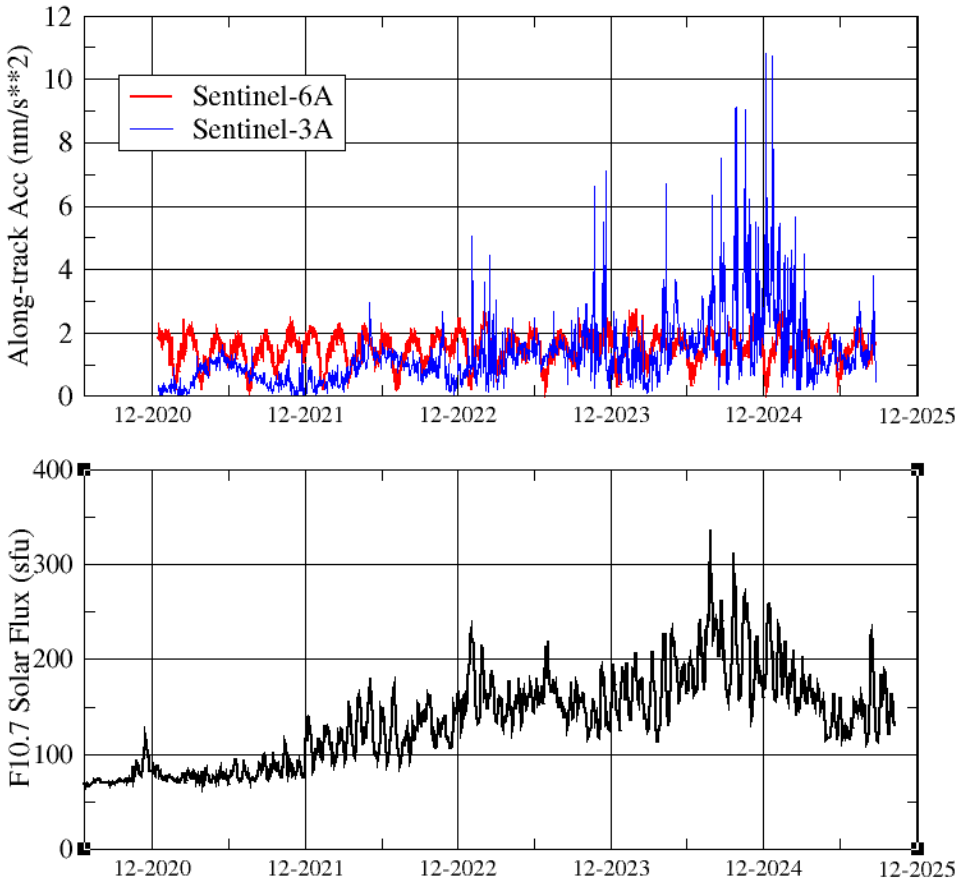
Analyze the impact of GPS Clock as the modelled DORIS USO on station position estimation for Sentinel Satellites

Finalize the integration of the SWOT satellite into the multi-satellite solution

Produce a DORIS multi-satellite tropospheric delay sinex product

Impact of increased solar activity on POD

❑ OPR Acceleration Amplitude (along-track)

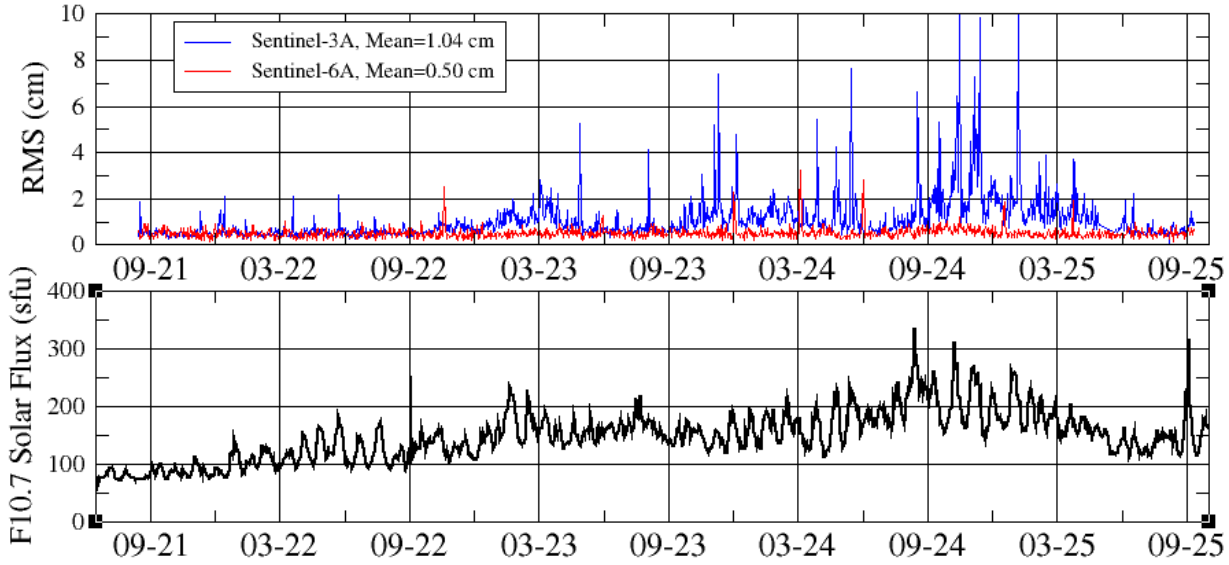


- *For Sentinel-3A, there is a degradation in the along-track amplitude from early 2023 as the solar flux increases. No impact for Sentinel-6A which has a higher altitude.*

❑ Comparison to POE-G orbit

Daily RMS radial orbit differences (in cm)

(from Aug. 2021 Sept. 2025)



- *For Sentinel-3A, the agreement between GRG orbit and POE-G orbit deteriorates as the solar flux increases.*
- *For Sentinel-6A, the agreement between GRG orbit and external orbit is similar over the entire period (~0.5 cm RMS), even when the solar flux is higher.*

Impact of increased solar activity

❑ Develop a strategy to mitigate the impact of increased solar activity on POD and the multi-satellite solution (preliminary study)

The atmospheric density varies significantly during periods of high solar activity, which strongly affects low-altitude satellites due to the difficulty of accurately modeling the atmosphere.

All DORIS satellites at lower altitudes are impacted (excluding Sentinel-6A and Jasons satellites which are higher).

First, we tried to adjust more drag coefficients (from 1 coefficient every 4 hours to 1 coefficient every hour), and we also tested other models of thermosphere (as NRLMSIS 2.0), but the results were not satisfactory.

We know that GPS orbits are less impacted by solar activity due to the increase in solar flux.
Indeed, in GPS processing, we can compute a reduced-dynamic orbit because the number of observations is much greater than in the case of DORIS processing over a pass duration.
Therefore, we attempted to adjust a stochastic force to mitigate the impact on DORIS-only orbits.

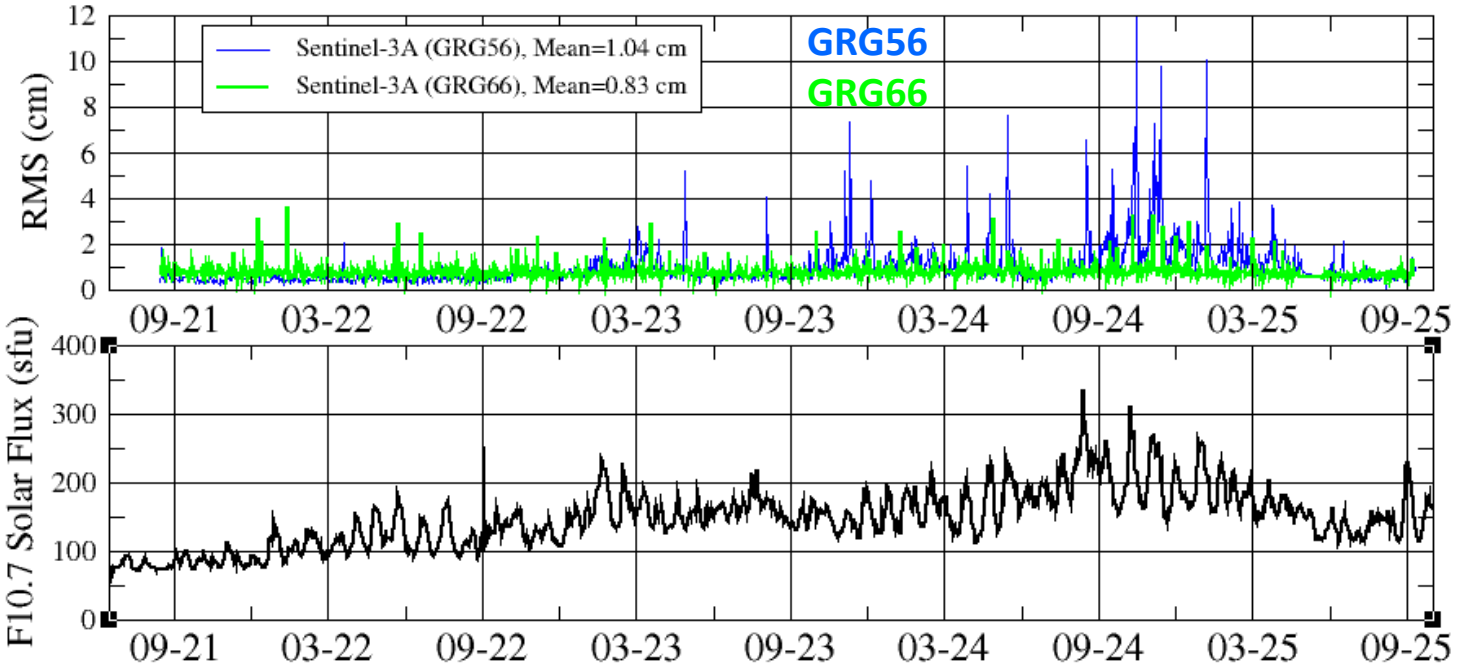
Then we created a new series, grg66, and processed DORIS data from August 2021 to September 2025, by adjusting one drag coefficient per hour and by adjusting a stochastic force every two hours.

Impact of increased solar activity on POD

❑ Comparison to POE-G orbit

Daily RMS radial orbit differences (in cm)

(from Aug. 2021 Sept. 2025)



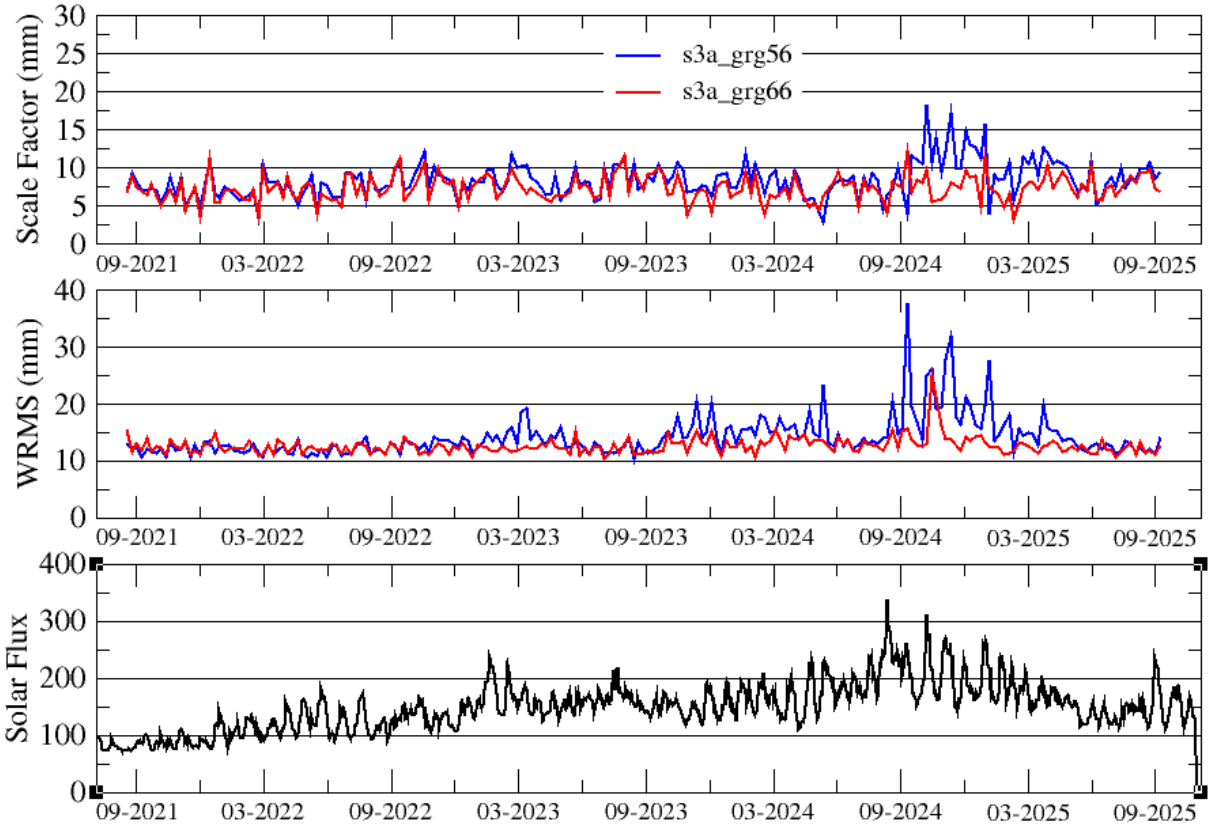
Orbit Comparison to POE-G (Mean of daily RMS (cm))			
	Radial	Along-track	Cross-track
GRG56	1.04	2.90	1.80
GRG66	0.83	2.30	1.74

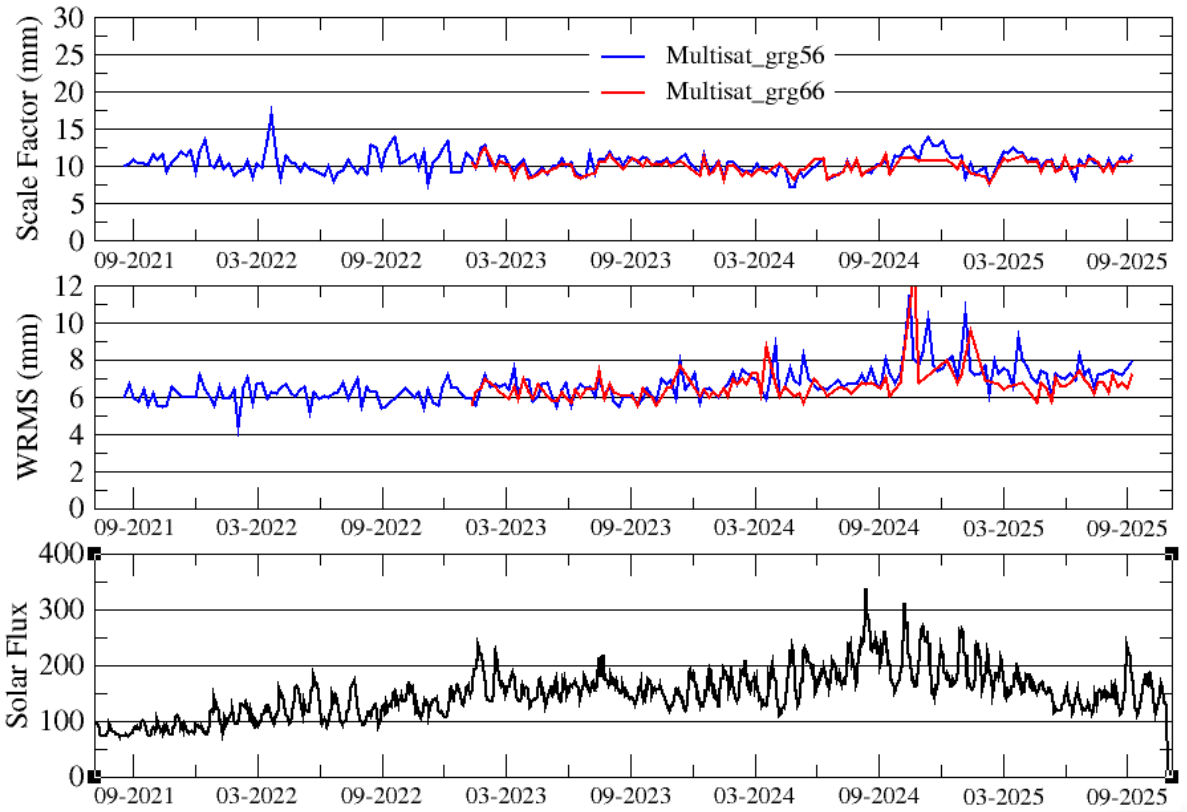
- *For Sentinel-3A, compared to the operational series grg56 (in blue), the agreement between the GRG orbit and the POE-G orbit improves when adjusting a stochastic force (grg66 in green) as solar flux increases. For the radial component, several peaks disappear. The mean daily RMS values are reduced for all components.*

Impact of increased solar activity on positioning

❑ Comparison of each solution to DPOD2020 (computed by CATREF)

Scale Factor from grg solutions (from Aug. 2021 Sept. 2025)



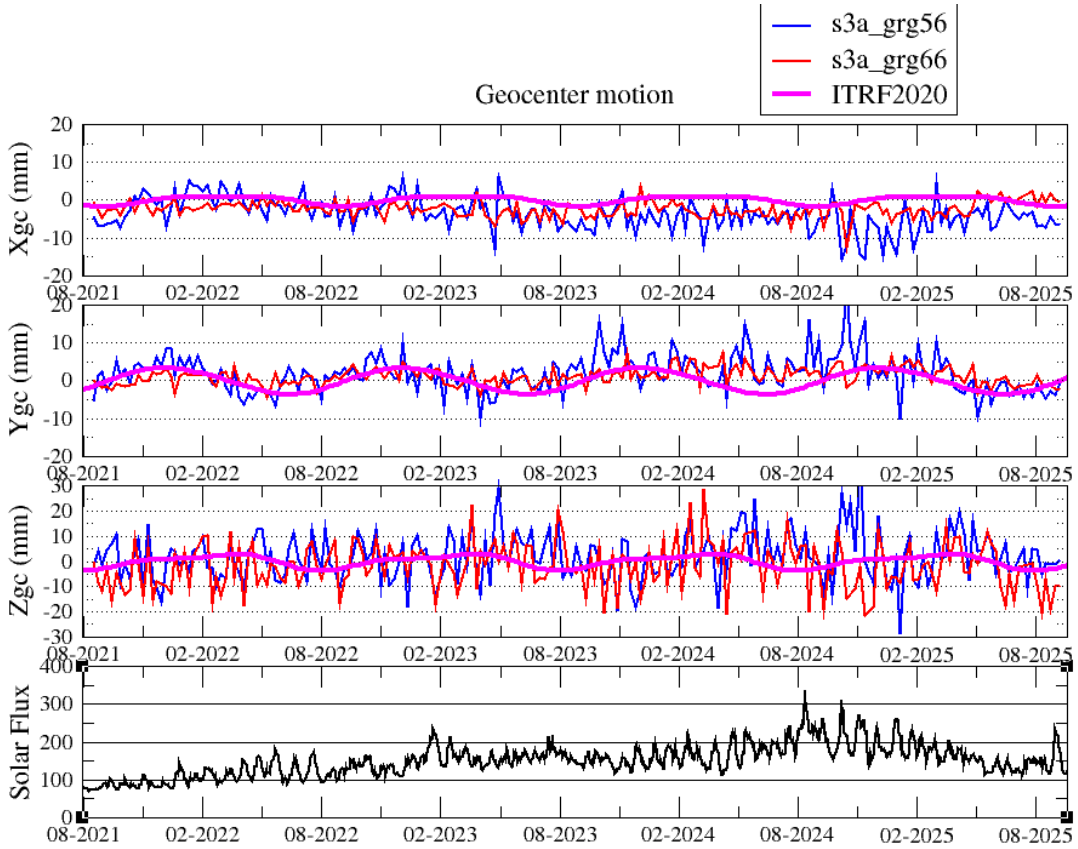


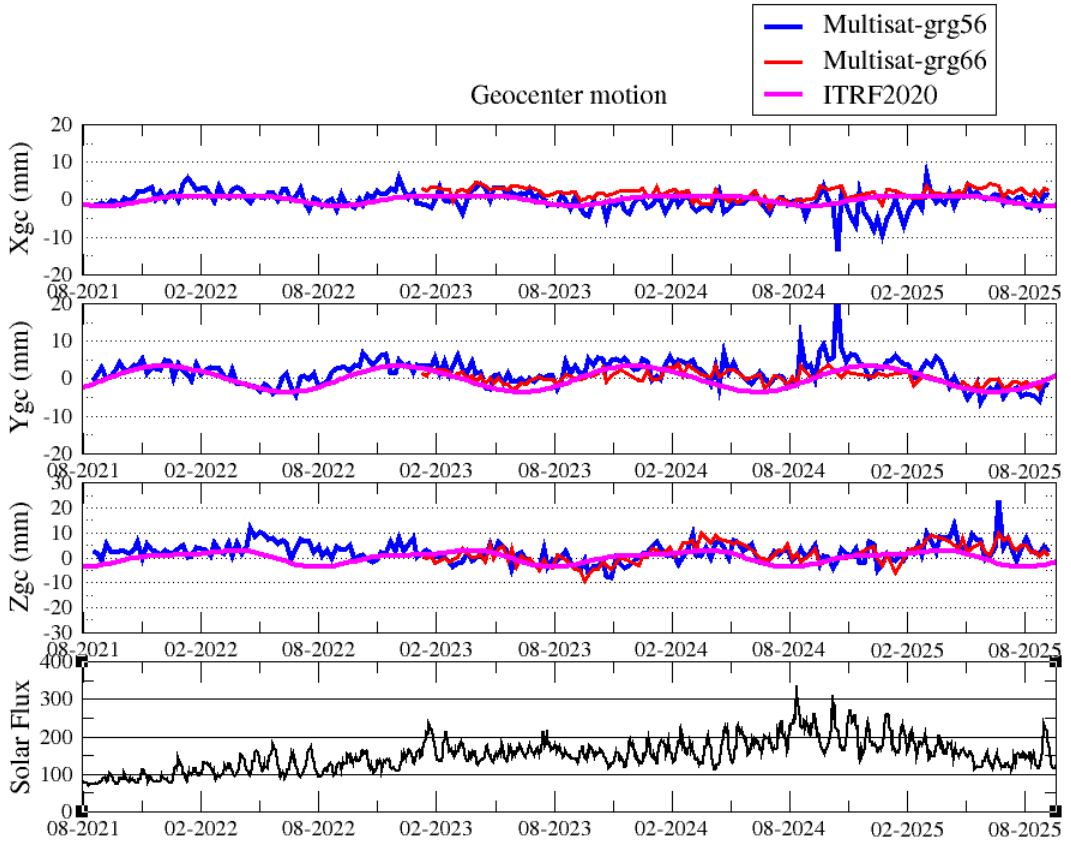
- *For low-altitude satellites, such as Sentinel-3A, the scale and WRMS of positioning are affected when solar flux becomes too high.*
- *The new series improves the solutions, although the improvement in the multi-satellite solution is less clear.*

Impact of increased solar activity on positioning

❑ Comparison of each solution to DPOD2020 (computed by CATREF)

Origin from grg solutions (from Aug. 2021 Sept. 2025)

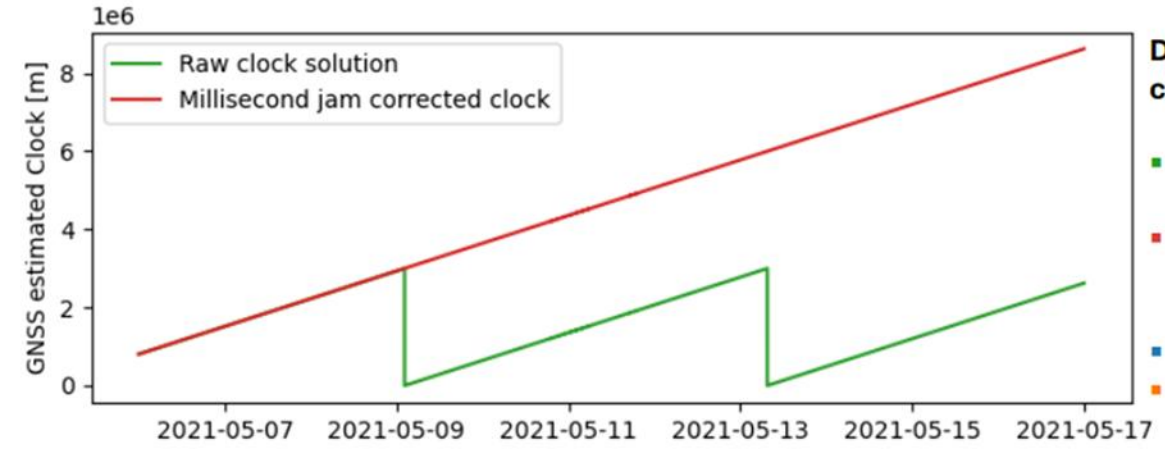




- *The new series provides better results for the geocenter, both for the Sentinel-3A solution and for the multi-satellite solution. The agreement between the grg66 multi-satellite solution and the geocenter from ITRF2020 is improved.*

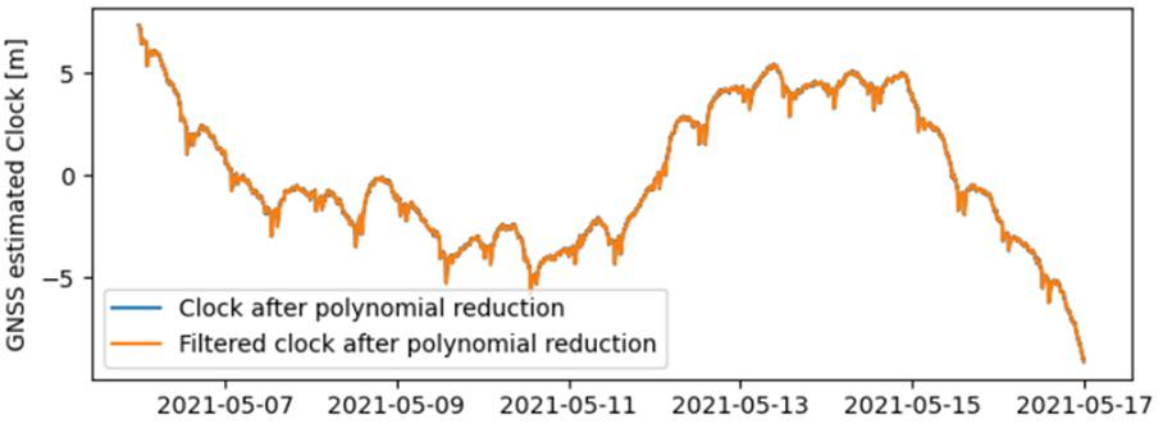
Analyzing the Impact of GPS Clock as the modelled DORIS USO on Station Position Estimation for Sentinel Satellites

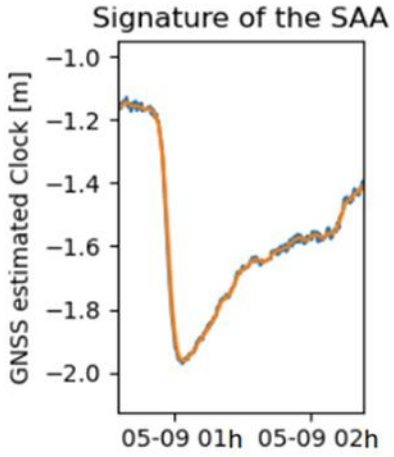
- **Here we determine the USO behavior from GNSS observations**



DORIS correction processing chain

- Raw GNSS clock estimation during orbit determination
- Removal of GNSS receiver corrections (here millisecond jumps for S3A)
- Polynomial reduction
- 5 minutes lowpass filtering





- We use the GNSS filtered clock provided by the CNES POD team within the framework of the International DORIS Service Working Group on “Integrated Clock Correction Strategies for DORIS.”
- These clock corrections are applied to the phase measurements (2 GHz and 400 MHz) in the DORIS RINEX files.
-

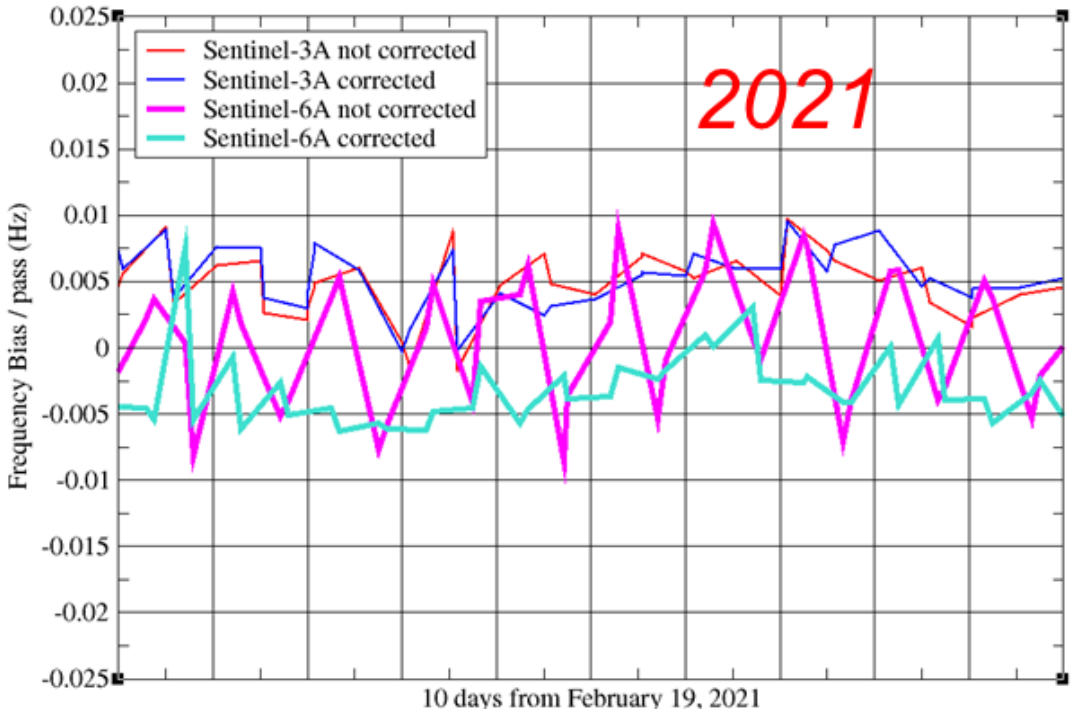
Results presented at EGU.

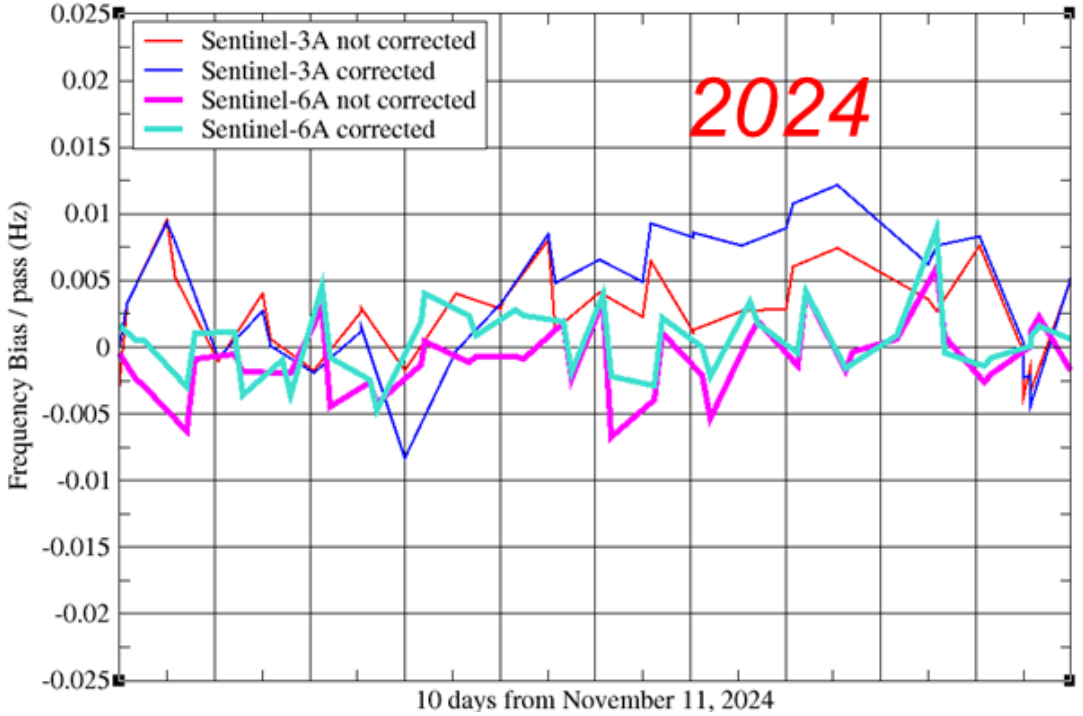
Impact of the integration of GPS clocks on the orbit

❑ **Parameter estimated per pass in GRG POD processing:**

Frequency bias/pass: Measurement frequency offset for Kourou (KRWB) in SAA area

Master beacon synchronized with an external cesium atomic clock providing high frequency stability





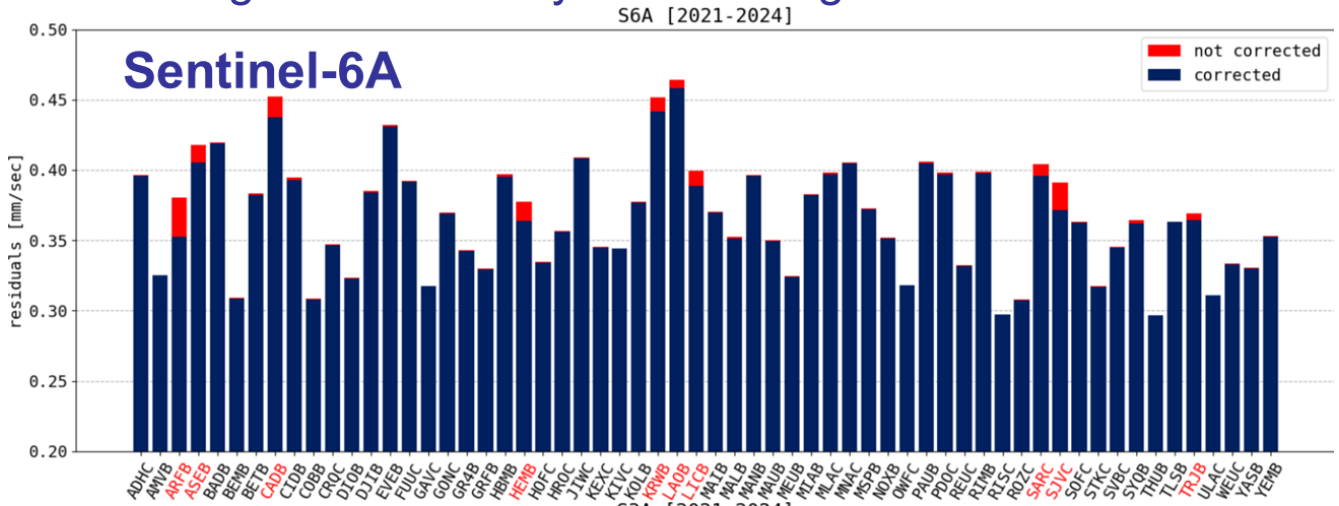
- *For Sentinel-6A:*

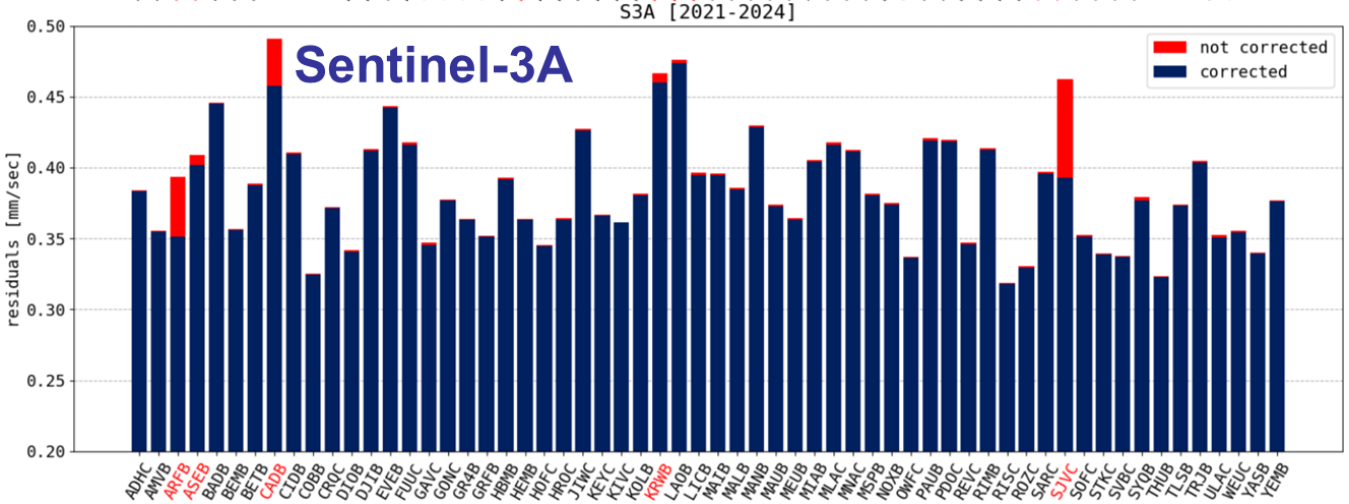
As shown by the impact on the frequency bias (magenta curves) the SAA impact in 2024 seems to be less significant than in 2021.

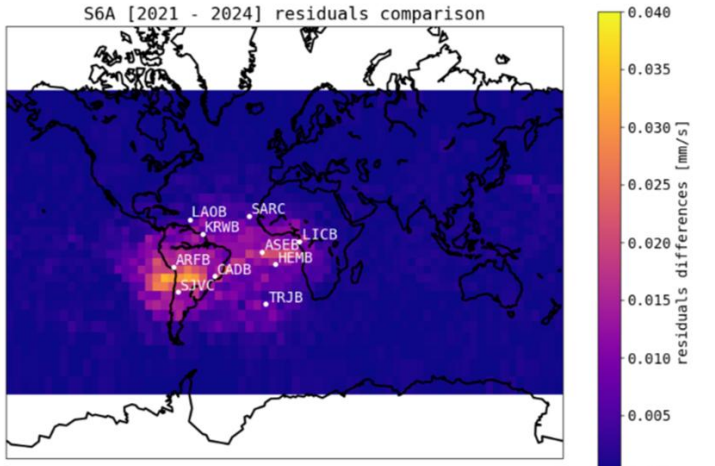
Impact of the integration of GPS clocks on the orbit

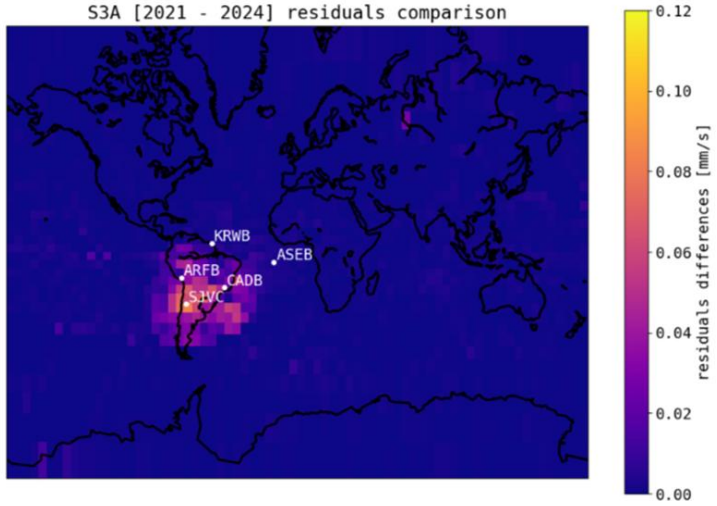
- **RMS of fit (in mm/s) per DORIS stations from GRG POD processing**

Average from January 2021 through December 2024









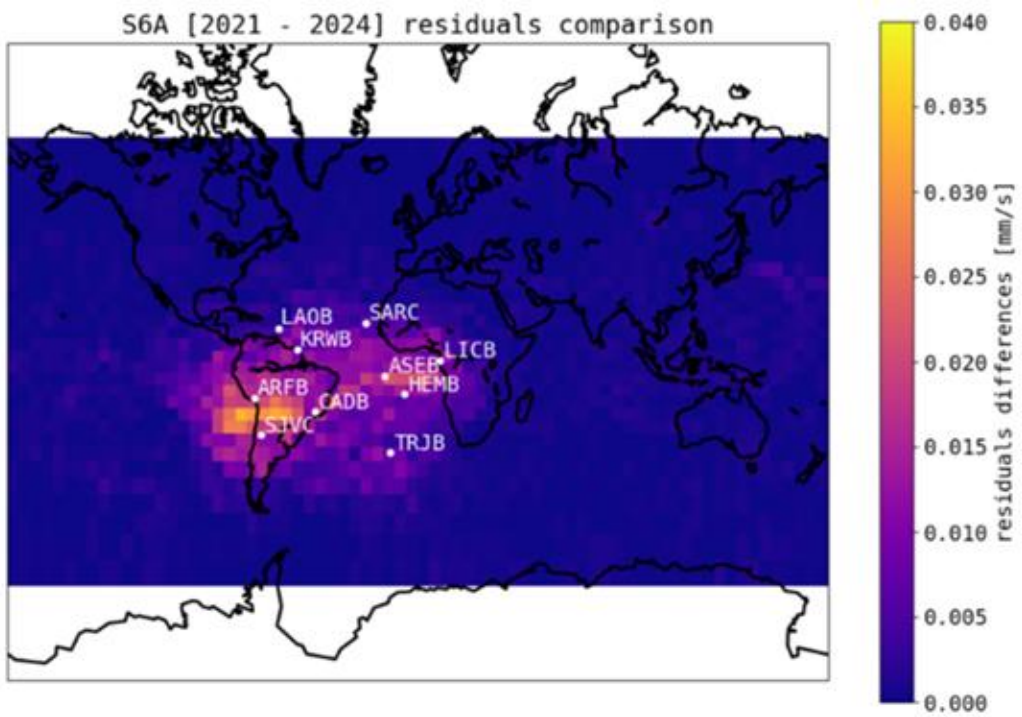
- *For Sentinel-6A and Sentinel-3A:*

The correction significantly reduces the RMS residuals of SAA stations.

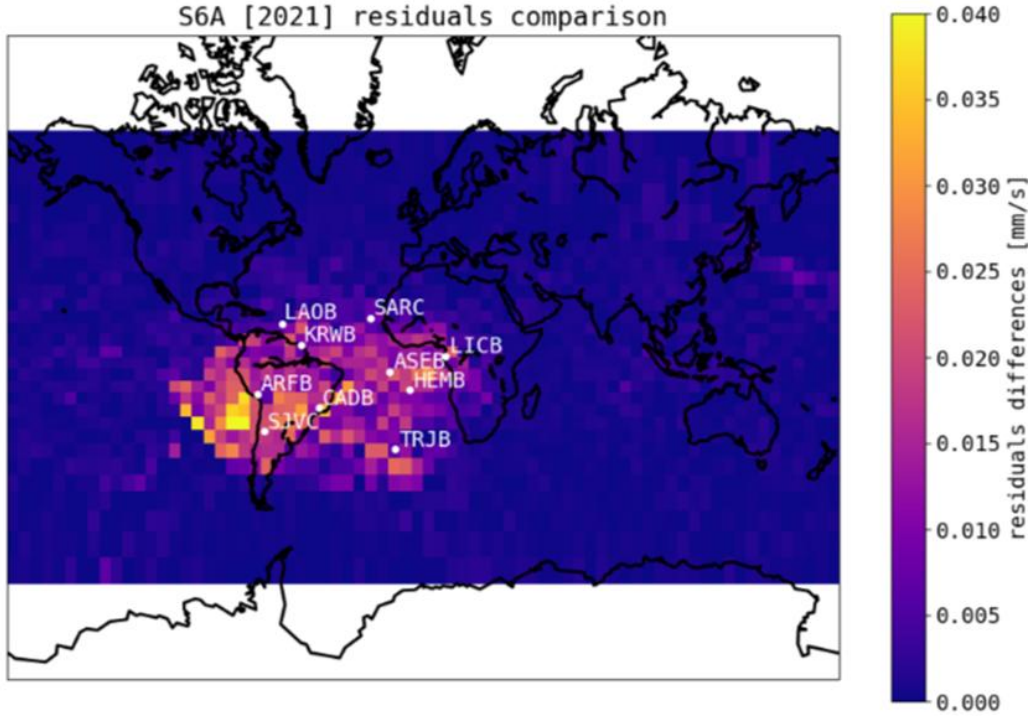
Impact of the integration of GPS clocks on the orbit

- **RMS of fit (in mm/s) per DORIS stations from GRG POD processing**

Sentinel-6A
Average from January 2021 through December 2024



Sentinel-6A
Average year 2021



- *For Sentinel-6A:*

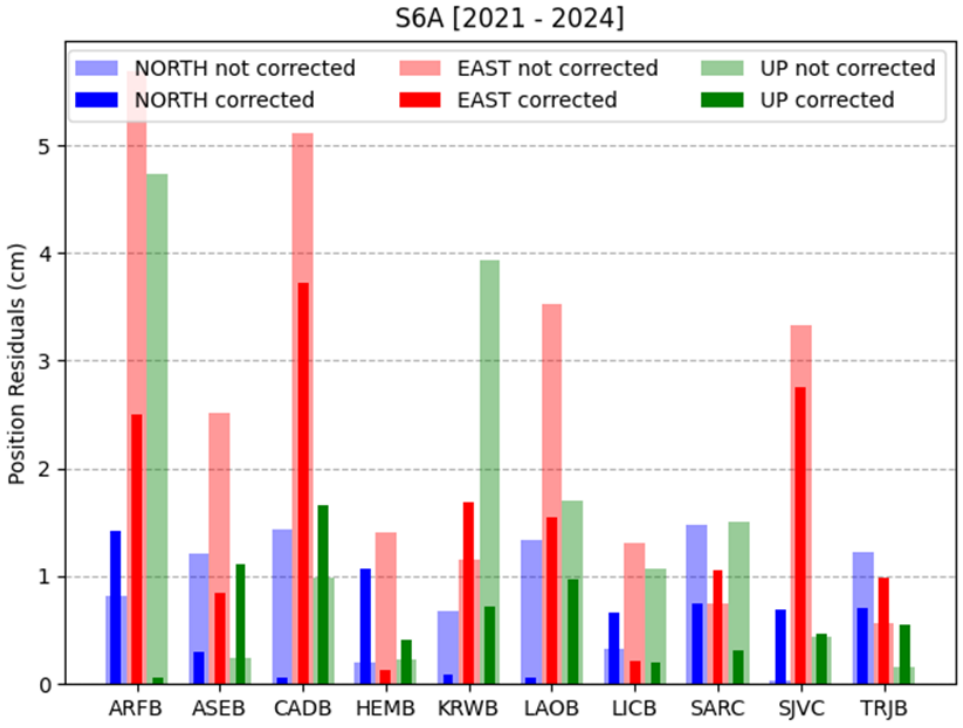
As shown by the impact on the frequency bias and on the 2021 map of RMS of fit per DORIS stations, the SAA impact in 2024 seems to be less significant than in 2021.

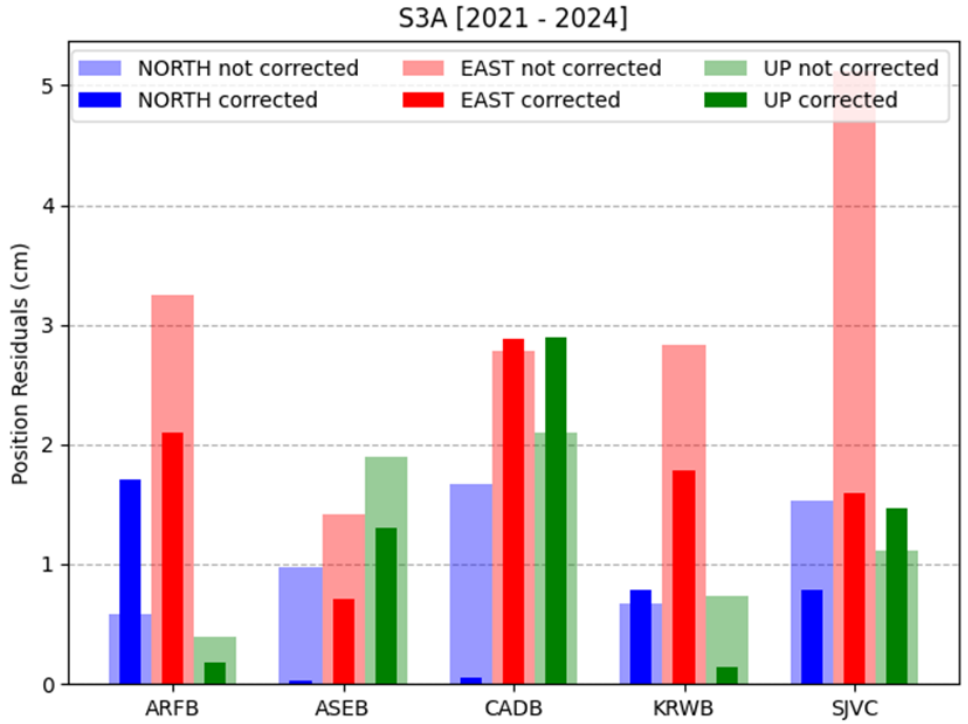
Impact of the integration of GPS clocks on the station position estimation

❑ Single satellite Solution compared to DPOD2020 (computed by CATREF)

Positioning Residual STD - Time series of DORIS coordinates wo and w correcting the SAA stations.

After removing the long-term trend, we compare the residual noise levels (STD) in NEU components.





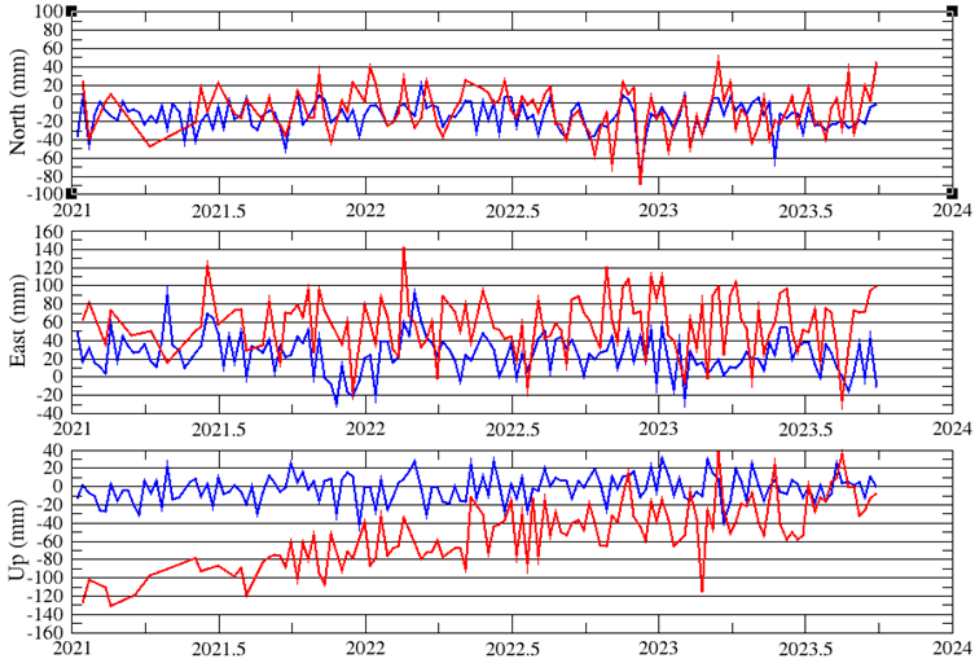
- *The integration of Sentinel GPS clocks significantly reduces the positioning residual standard deviation (STD) for stations located in the SAA area.*

Impact of the integration of GPS clocks on the station position estimation

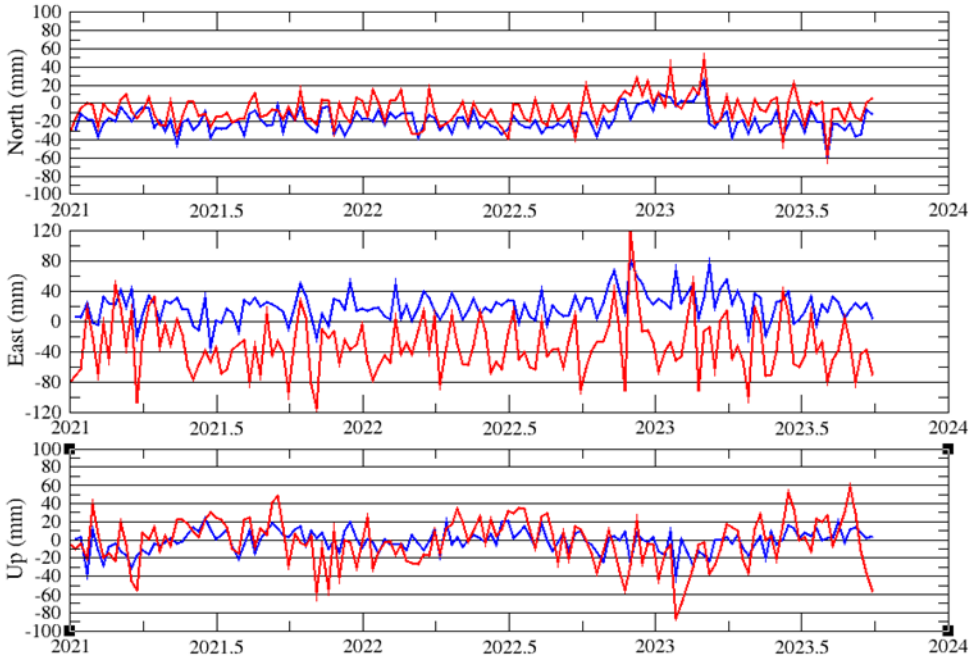
❑ **Single satellite Solution compared to DPOD2020 (computed by CATREF)**

Time Series of SAA DORIS station positions

Arequipa (ARFB) from Sentinel-6A



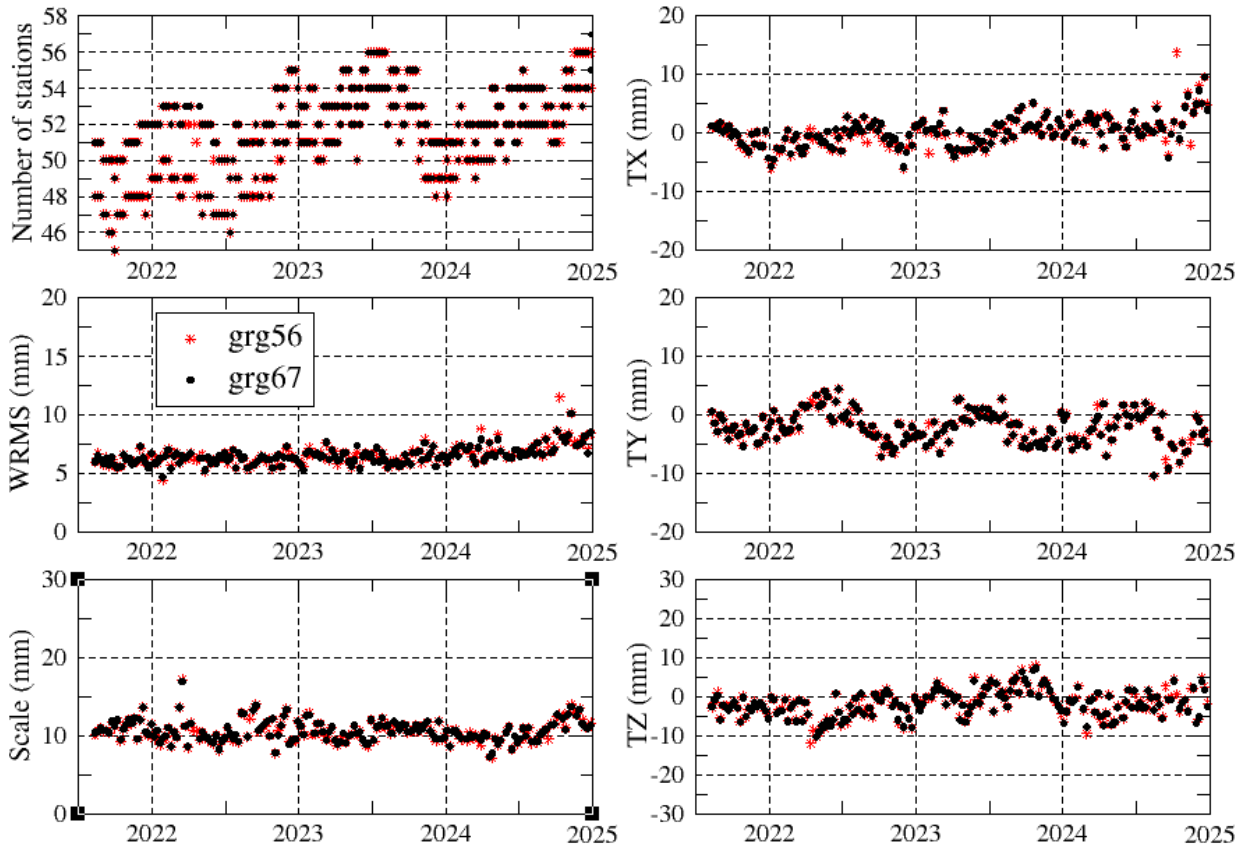
Arequipa (ARFB) from Sentinel-3A



- *The integration of Sentinel GPS clocks significantly reduces the non-physical drift in time series and the positioning residual standard deviation (STD) for stations located in the SAA area. For Sentinel-6A, according to the time series of DORIS station positions, the impact of the SAA in 2024 appears to be less significant than in 2021.*

Impact of the integration of GPS clocks on the station position estimation

- **Multi-satellite Solution compared to DPOD2020 (computed by CATREF)**



- *We obtain the same results when we apply the mitigation strategy to Sentinel-6A and Sentinel-3A (grg56) while using clock corrections.*

Future work

We plan to continue

- *to analyze Origin and Scale factor from single satellite and multi-satellite solutions*
- *the evaluation of GRG orbits:*
  - *by comparisons to internal orbits with GNSS*
  - *by comparison to external orbits*
  - *by Independent SLR RMS of fit*
  - *by Altimeter crossover Cycles*
- *to develop the strategy to mitigate the impact of the increased solar activity*
- *to finalize the introduction of SWOT in the multi-satellite solution*
- *to contribute to the IDS Working Group:*

Analyzing the Impact of GPS Clock as the modelled DORIS USO on Station Position Estimation for Sentinel Satellites (extension of Sentinel-3A period, evaluation for Sentinel-3B, test GMV clock corrections)

- *the preparation for the GENESIS mission: GEODESIS: Tri-technique (SLR+GNSS+DORIS) combination for LEO single satellites as Sentinel-6A, 3A&B, Jason-3 ..*
- *to produce a DORIS multi-satellite tropospheric delay*
- *to work on DORIS scale, try to explain the bias vs ITRF2020 (other technics, around 5-10 mm)*