IDS Workshop **2026**

Stochastic processing in POE-G standard

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IN PARTNERSHIP WITH

Summary

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CRYOSAT-2 RESULTS

CONCLUSION

CONFIGURATION

CNES Precise Orbit Determination standard POE-F , DORIS-only reduced dynamic solution, with 1/rev along/cross-track and constant along-track empirical accelerations, estimated with relative constraints every orbital revolution and 30 minutes, respectively.

CRYOSAT-2 mission

- altitude 717 km, inclination 92°
- DORIS system
- Good S/M ratio, convex platform and good SRP modeling

OBSERVATIONS

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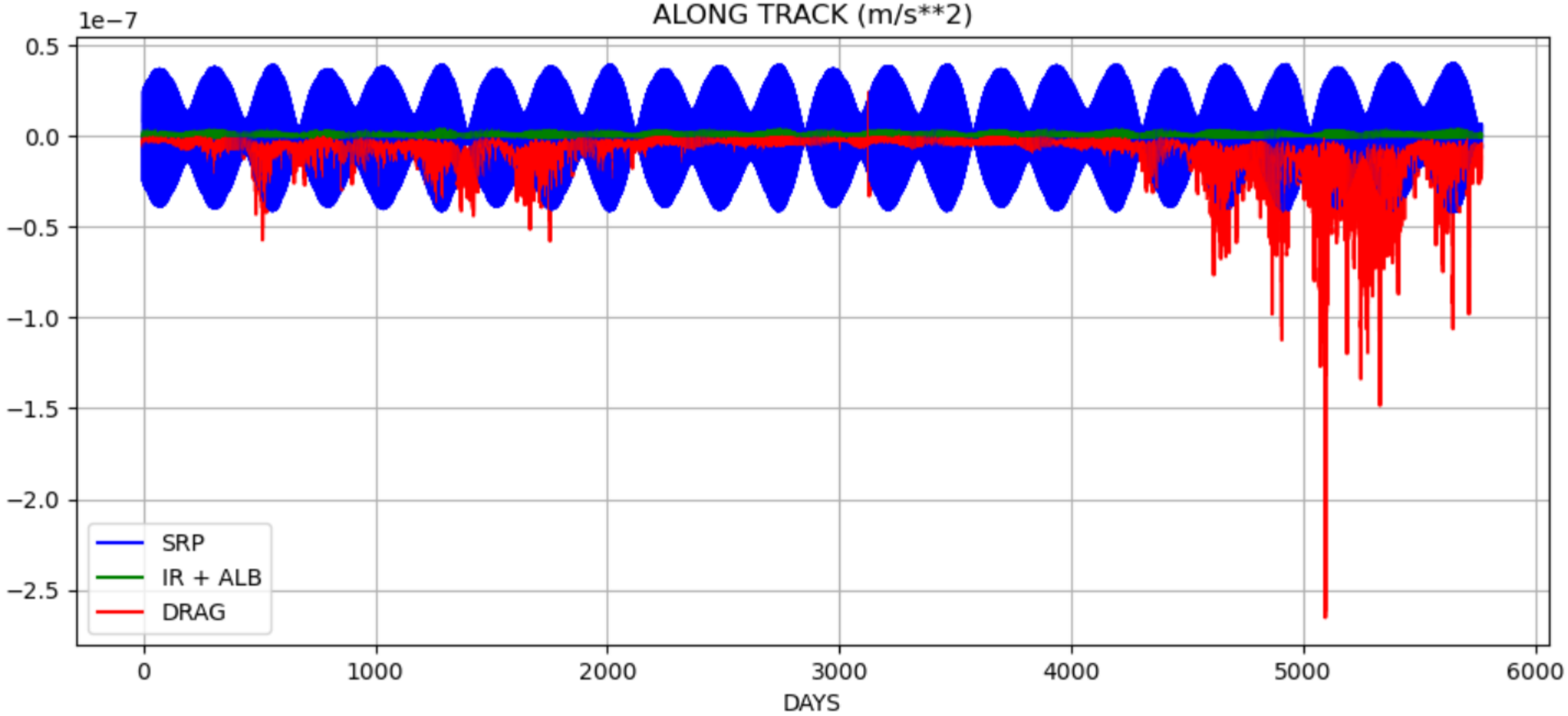
Depending on the solar activity, the drag acceleration may be the main perturbing force in the along-track direction



CRYOSAT-2 accelerations with adjusted drag coefficients every 6 hours

OBSERVATIONS

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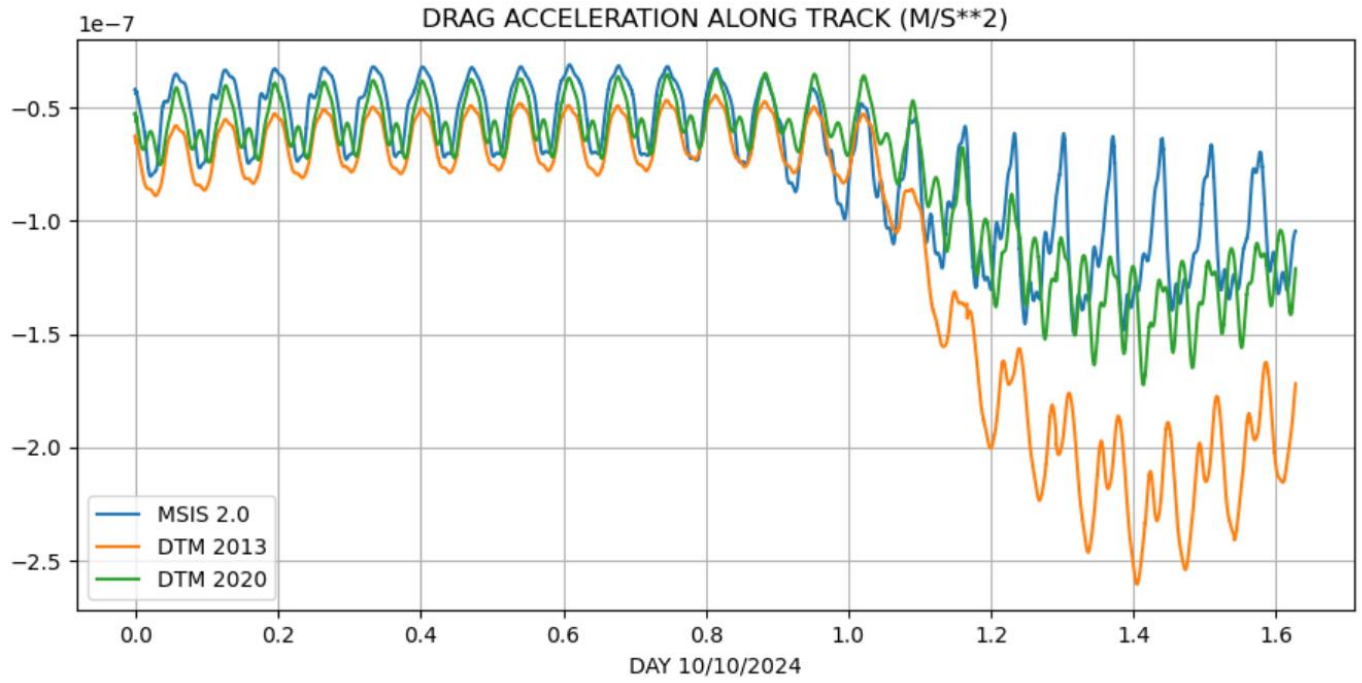
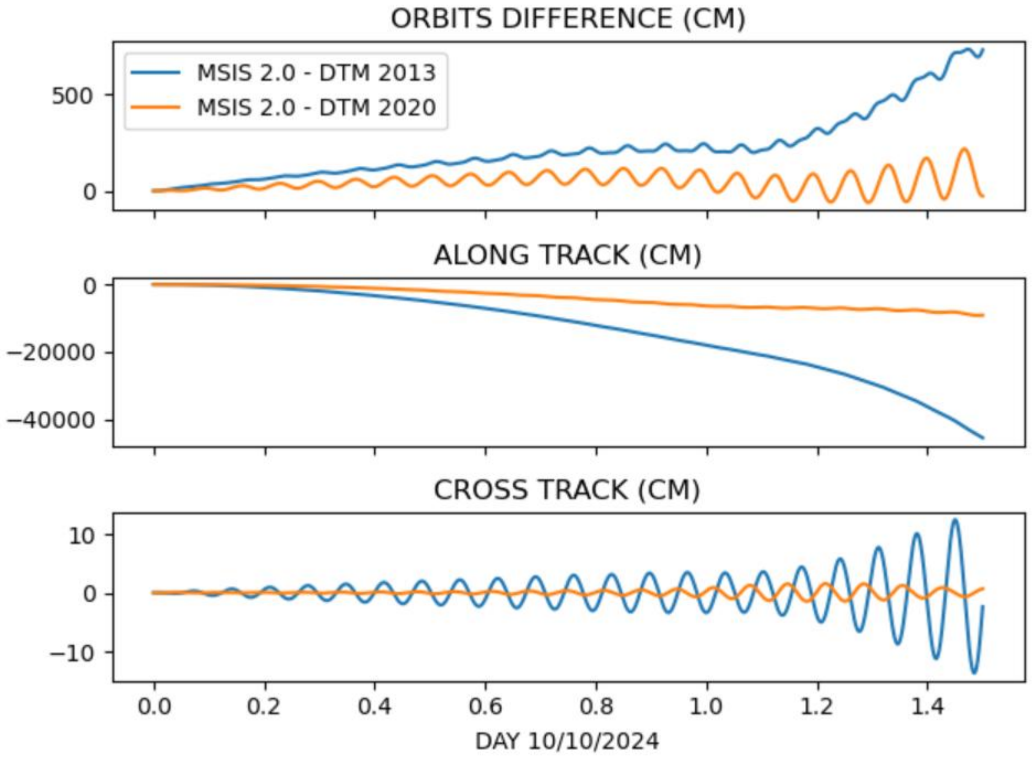
The behaviour of the drag models could be significantly different :



CRYOSAT-2 drag accelerations using different models



Extrapolated orbit differences

In an operational context, some manual parametrization could be needed to handle the high solar activity

OBSERVATIONS

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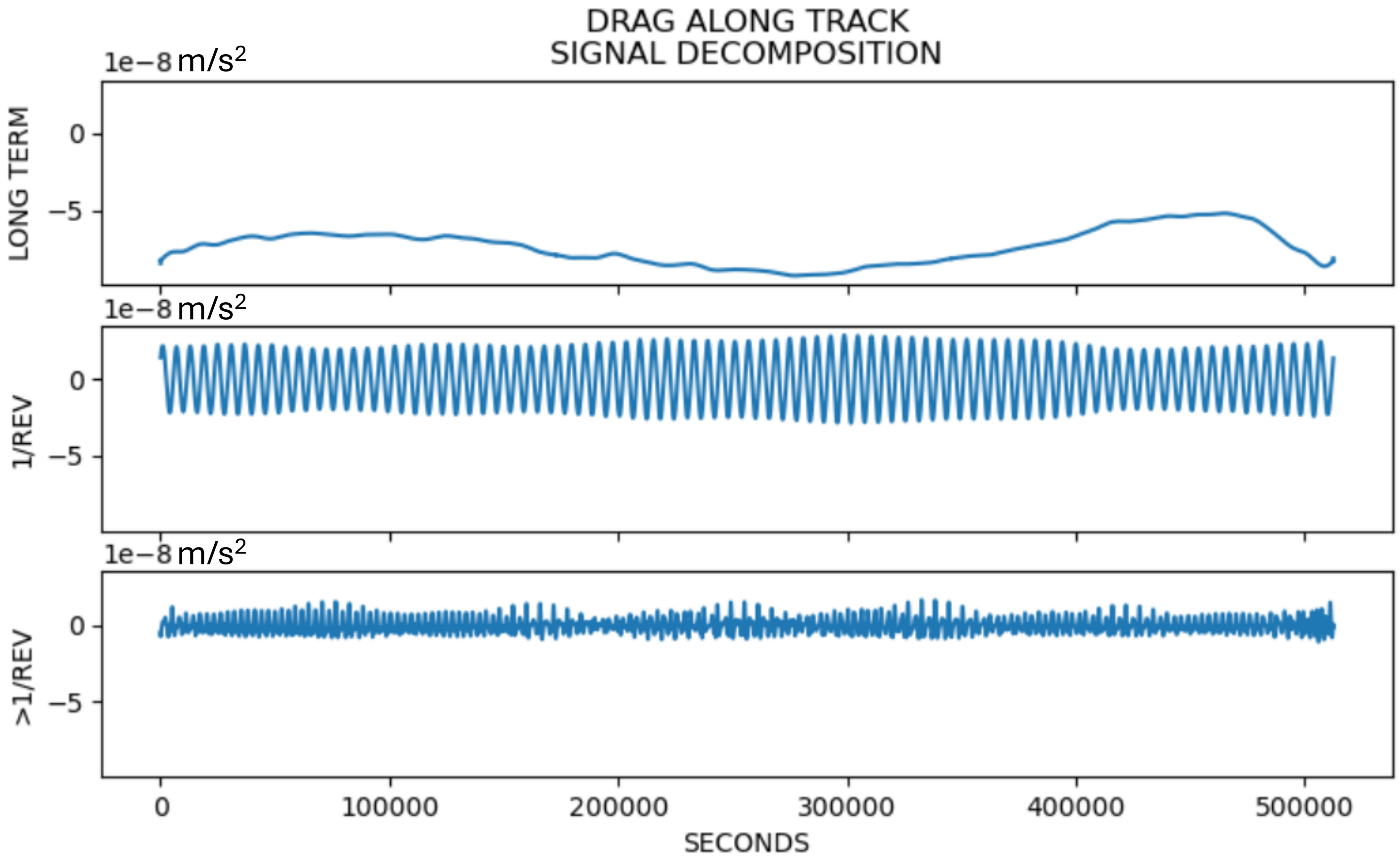
Along track drag acceleration, CryoSat-2 arc 757, MSIS 2.0 model

The bias evolution of the long term component is not the same as the amplitude of the 1/REV
→ Estimating some constant accelerations to mitigate the drag modeling errors is not sufficient

The amplitude of the high frequency component (>1/REV) is half of the 1/REV
=> Not so negligeable



OBSERVATIONS

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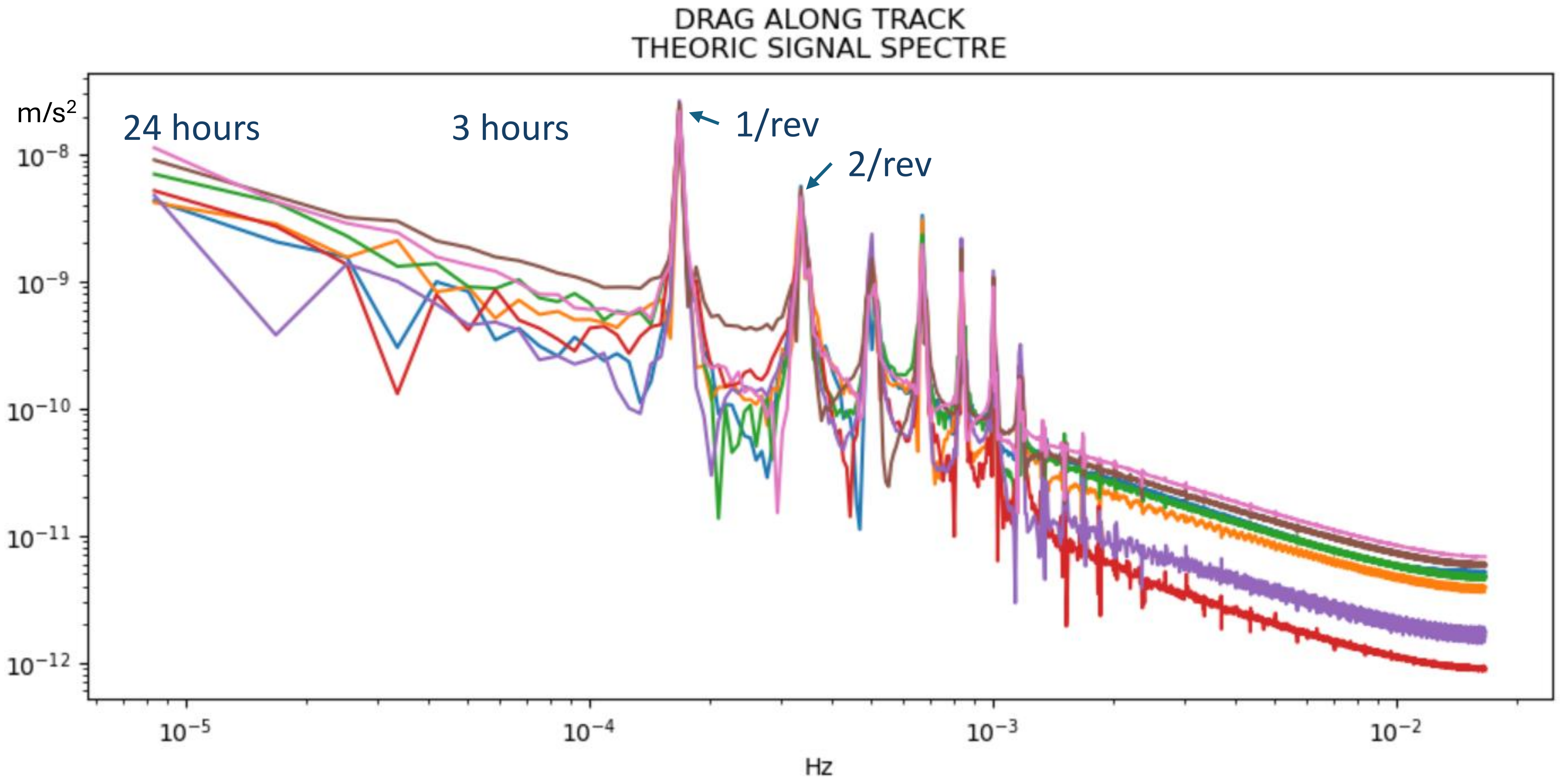
Along-track drag acceleration, CryoSat-2 arc 757, MSIS 2.0 model



The geomagnetic index period of 3 hours has no impact on the signal spectrum

OBSERVATIONS

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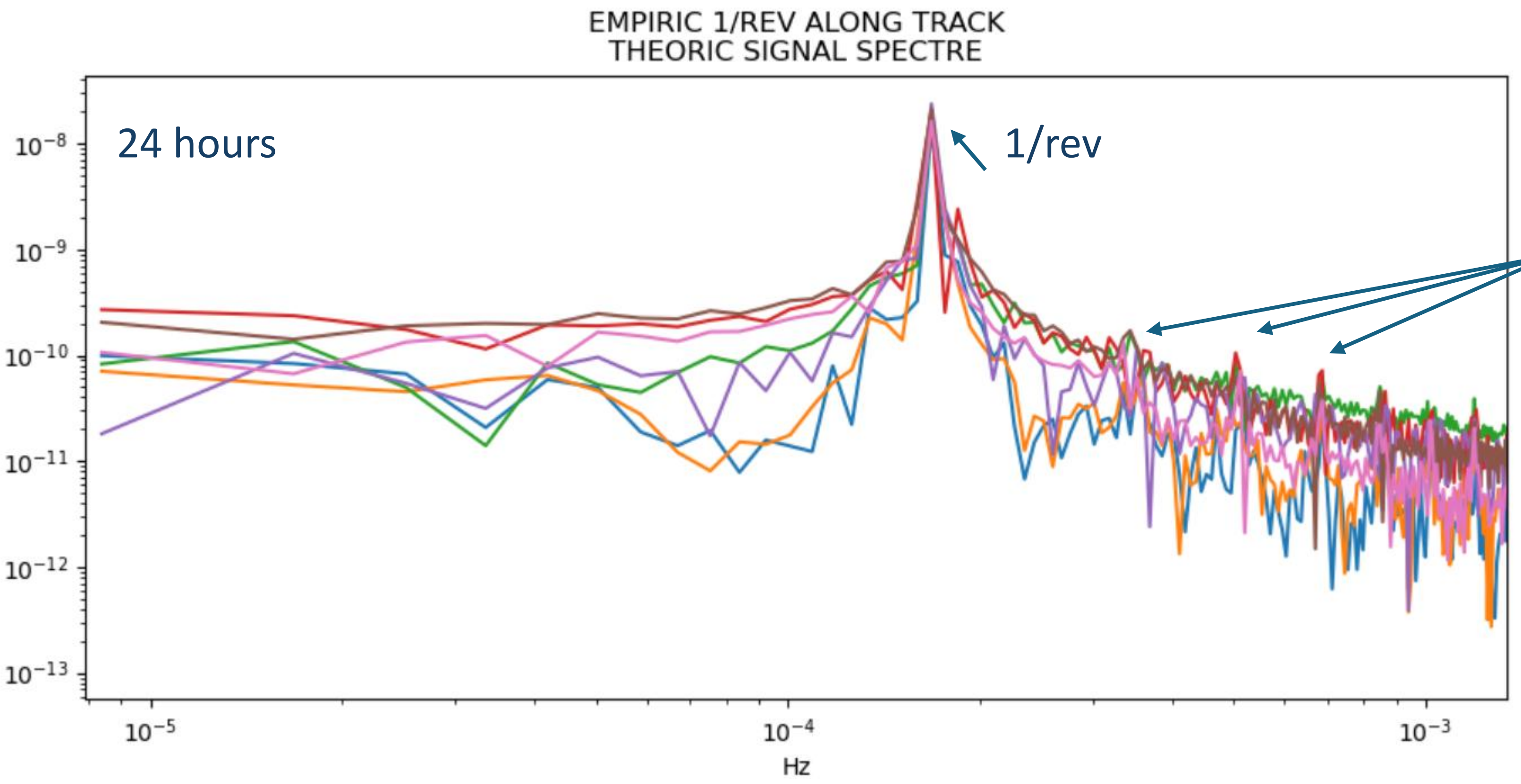
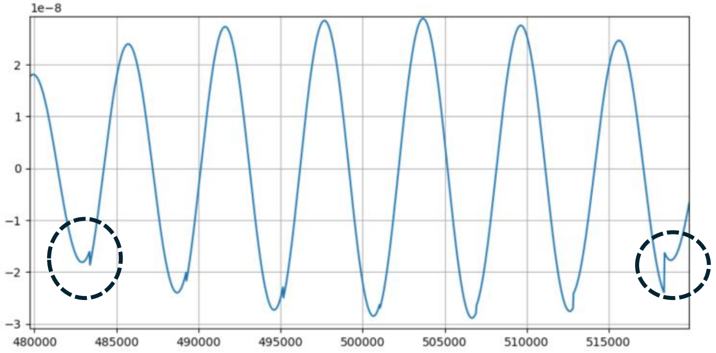
Along-track 1/rev empirical accelerations, CryoSat-2 arc 757, MSIS 2.0 model



Possible artefacts linked to 1/REV segments (phasing issues):



STOCHASTIC PROCESS

Stochastic approach in CNES POD software ‘ZOOM’ using first-order Gauss-Markov processes

Random acceleration error x^k with a covariance matrix *P*, segments of period h, correlation period τ

$$x_{k+1} = a x_k + v_k$$
$$a = e^{-h/\tau}$$

with 0 < a < 1

Covariance matrix

$$P = \sigma_x^2 \begin{bmatrix} 1 & a & a^2 & a^3 & \dots \\ a & 1 & a & a^2 & \dots \\ a^2 & a & 1 & a & \dots \\ \dots & & & & \\ \dots & & a & 1 & a \\ \dots & & a^2 & a & 1 \end{bmatrix}$$

Initial condition

$$E(x_0 x_0) = \frac{\sigma^2}{1-a}$$

Variance at each date

$$\sigma_x^2 = \frac{\sigma^2}{1-a}$$

STOCHASTIC PROCESS

Least square criterion method

$$J(x_d, x) = (y_{mes} - y(x_d, x))^t P_{mes}^{-1} (y_{mes} - y(x_d, x)) + x^t P^{-1} x$$

x_d: dynamic / measurement parameters

x: stochastic parameters

First term: Measurement residuals

Second term: stochastic residuals

Algorithm in 2 steps

Dynamic minimisation (dynamic solution x_{d0})

$$J(x_d, 0) = (y_{mes} - y(x_d, 0))^t P_{mes}^{-1} (y_{mes} - y(x_d, 0))$$

Stochastic minimisation (taking into account x_{d0})

$$J(x_{d0}, x) = (y_{mes} - y(x_{d0}, x))^t P_{mes}^{-1} (y_{mes} - y(x_{d0}, x)) + x^t P^{-1} x$$

STOCHASTIC PROCESS

Dynamic and stochastic configuration

DYNAMIC	STOCHASTIC
7-day processing Drag coefficient estimated every 6 hours 1/REV along/cross-track empirical accelerations estimated every 24 hours ith an absolute constraint of 1.E-7 m/s^2	7-day processing Period of segments h = 120s Correlation period τ = 600s Stochastic parameters in along/cross-track directions Sigma depending on drag force behaviour

CRYOSAT-2 RESULTS

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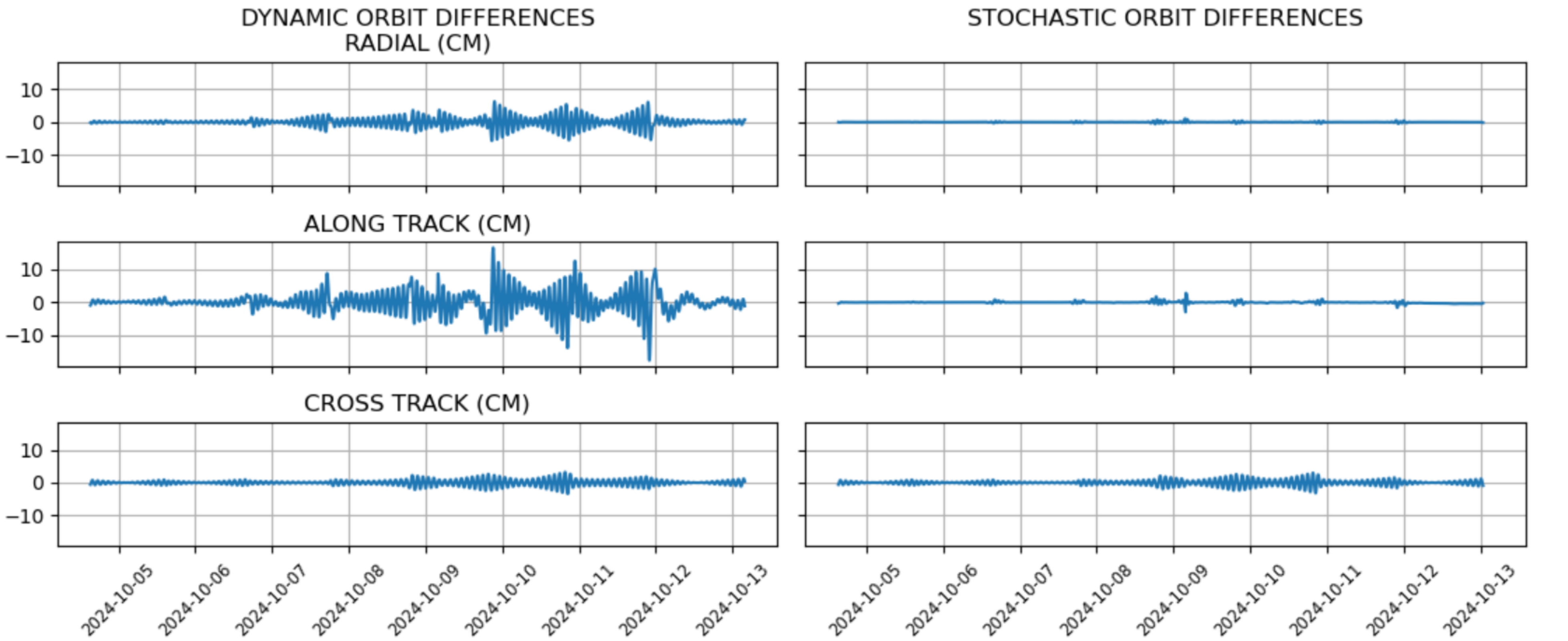
Arc 757 with a high solar activity period on October 10, 2024

In the dynamic parametrization, 1/REV empirical periods of 24 hours are shifted of 6000 seconds.

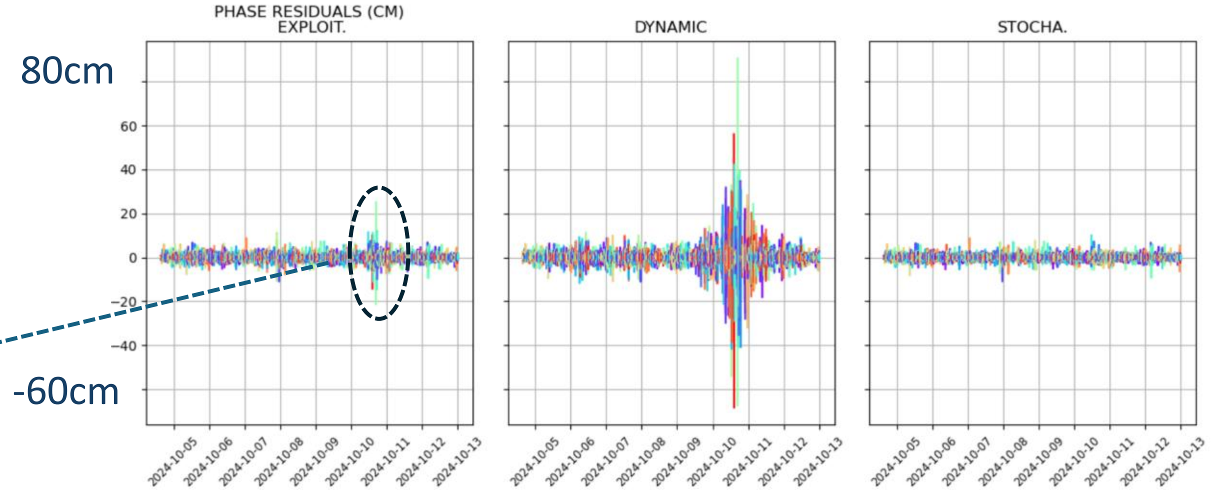


The impact is significant for the dynamic orbit in the along-track and radial components.
The stochastic orbit is more robust.

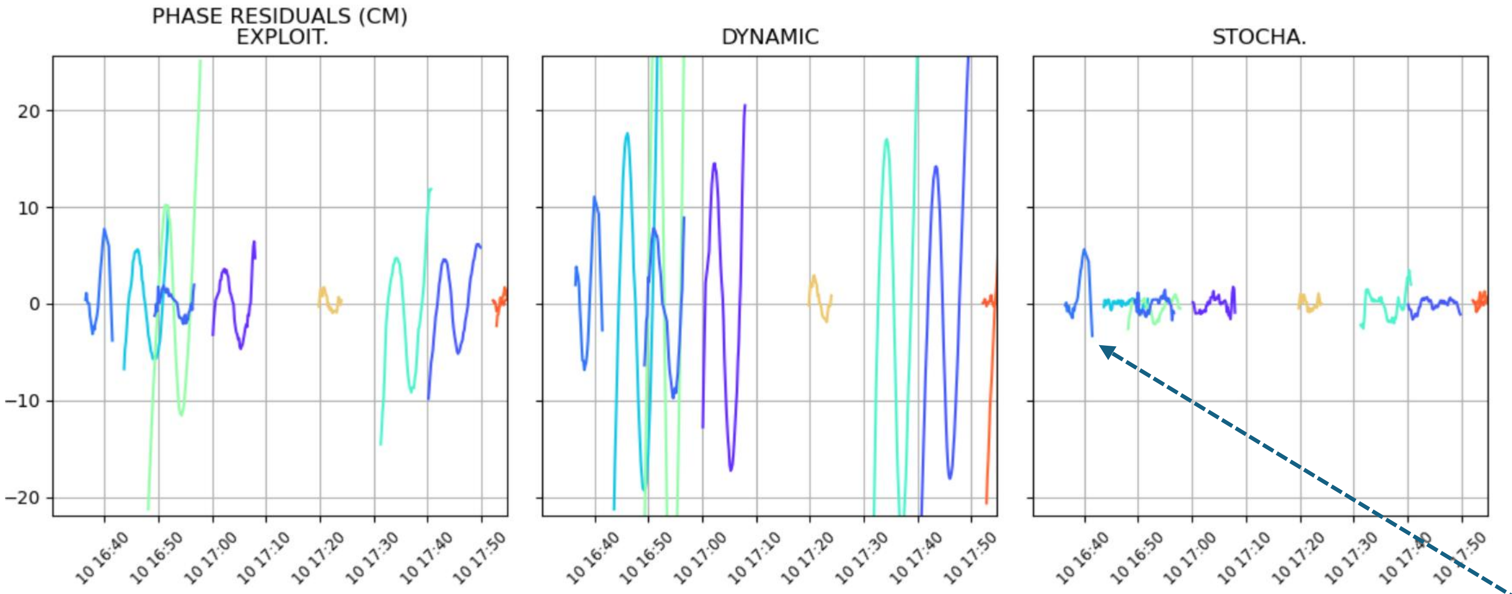
CRYOSAT-2 RESULTS

Arc 757 with a high solar activity period on October 10, 2024

Phase residuals comparaison on a 7-day arc



Orbits residuals from the 2-step stochastic process



Stochastic pulses are able to reduce phase residuals of several 10-centimeter levels

But some passes still show along-track delay signatures (i.e. 16h40)

CRYOSAT-2 RESULTS

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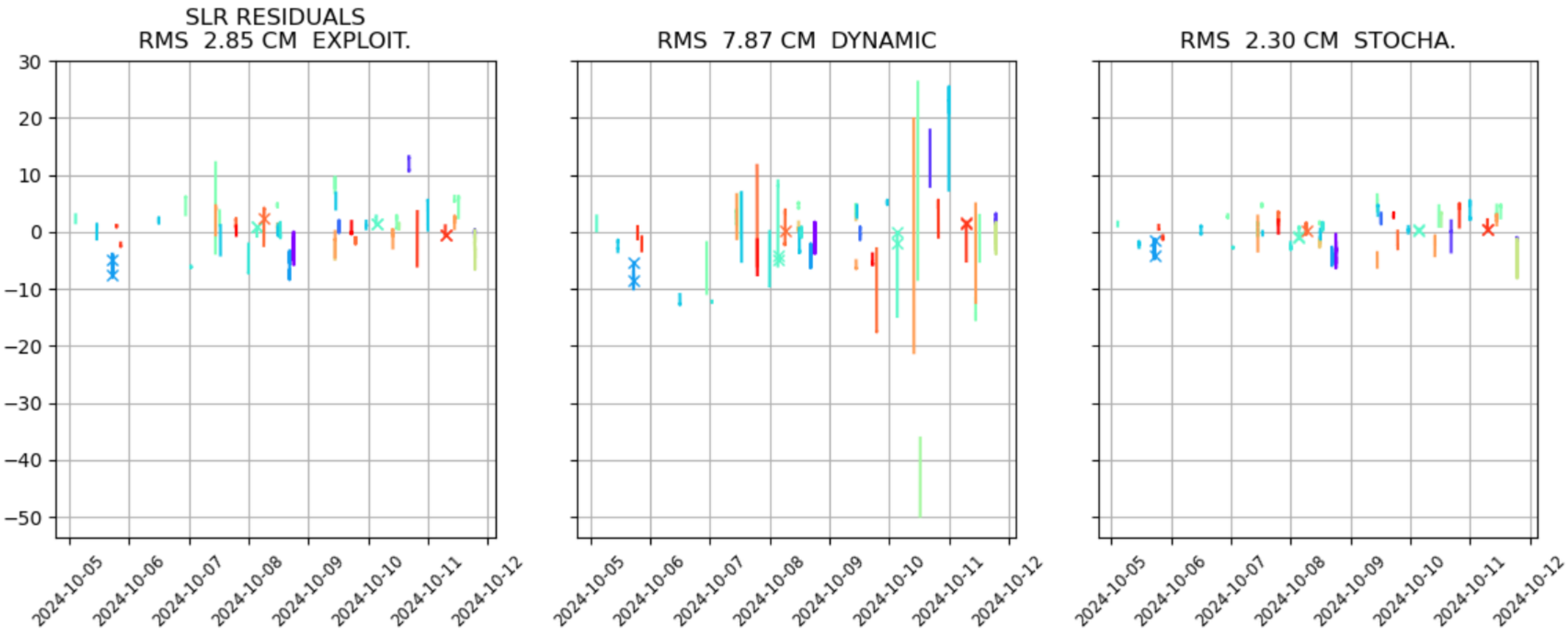

Arc 757 with a high solar activity period on October 10, 2024
SLR residuals comparaison on a 7-day arc
The residuals of the stochastic orbit show a better centering in general, and have a better standard deviation

CRYOSAT-2 RESULTS

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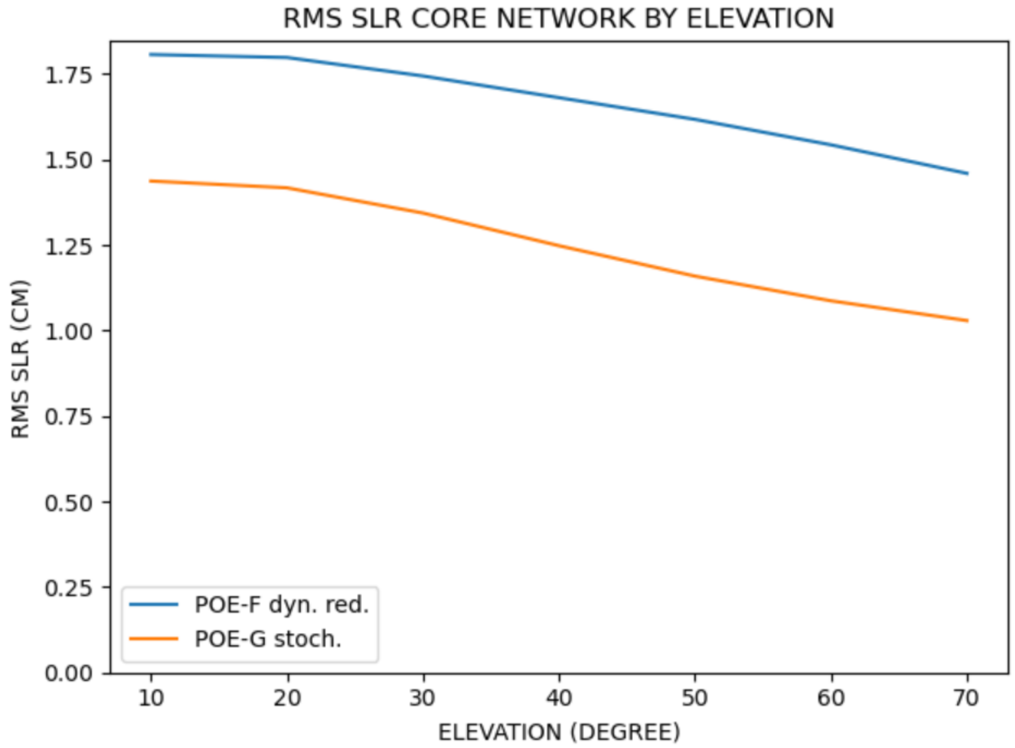

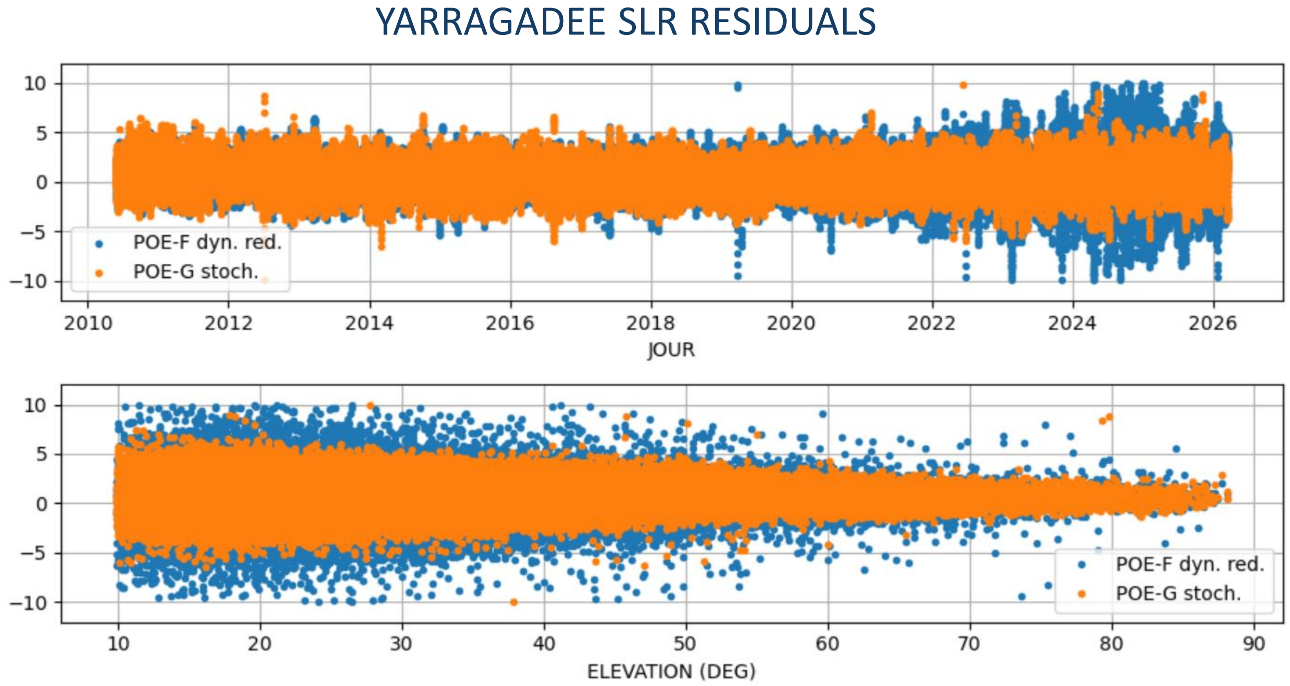

SLR comparison from the beginning of the mission -> mid-march 2026

The performance improvement observed here is mainly due to the change of standard, and then by the behaviour of the stochastic process (robustness is expected, performance improvement is the cherry on the cake)

CONCLUSION

Stochastic processes are integrated in POE-G to increase robustness

The efficiency of the algorithm and its implementation is able to estimate stochastic parameters on thousands of segments

Stochastic processes are less sensitive to measurement issues than the reduced dynamic, i.e. obtain 'good residuals' with an orbit performance degradation

The CryoSat-2 mission is the first based on this stochastic implementation

In the upcoming weeks, CNES CryoSat-2 operationnal processing will have a specific monitoring, to have a feedback in NTC orbit solutions