

Reprocessing of CryoSat-2

Do solar cycles affect the quality of orbits?

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CryoSat-2 reprocessing

POD setup Models and Data

- Coordinates for DORIS and SLR
 - DPOD2020 version 6.0
 - SLRF2020 version 250513
- Doppler IDS format 2.2 ten second integrated
 - Beacon frequency offset estimated by pass
 - Tropospheric zenith delay estimated by pass
- Laser data from ILRS, calibration data applied.
- Earth rotation parameters from IERS EOP 2020 C04
- Nominal arc length is 6 days with 1 day overlap
- Initial state vector from DIODE navigator orbits
- DORIS station weights determined by screening residuals

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POD setup Models and Data

- Gravity models, static part is EIGEN-6S4-V2 at reference 1-jan-2016
- SRP modelling, scaling constant 1.0295
- Panel model from CNES, antenna offsets from ESA
- Star tracker quaternions for S/C from ESA, reprocessed to body frame
- Drag modelling, MSIS reference model, 3 hourly patches with constraints
- Ocean tide modelling,
 - Load tide via FES2014 and Chalmer load tide calculator
 - Gradient of potential affecting the orbit via GOT 4.7 setup
- Empirical accelerations modelling, 6 hourly, piecewise modelled
 - Along and cross track, cos/sin/bias setup
- GEODYN software of the NASA/GSFC is used, added our own tools

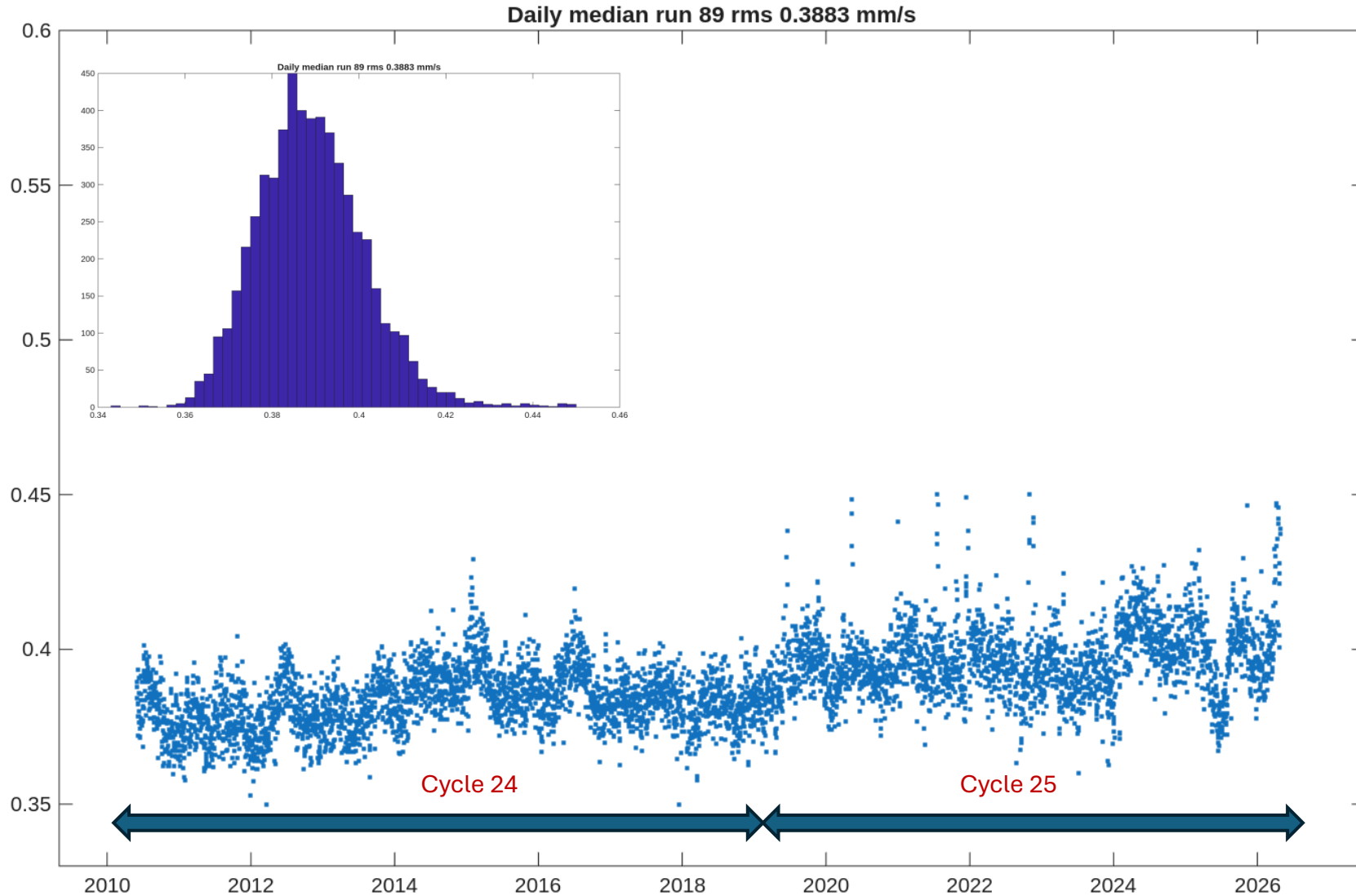
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TWS modelling from GRACE and GRACE-FO

- TWS: Terrestrial water storage
 - GRACE CSR 6.0 since April-2010,
 - GRACE CSR 6.3 since June-2018
 - Data gap from 23-5-2017 to 15-6-2018
- EOF compression and editing resulting in monthly grids
- Fourier approximation with local patch functions
- End result is added to the background gravity model
- TWS modelling is an option that we explore

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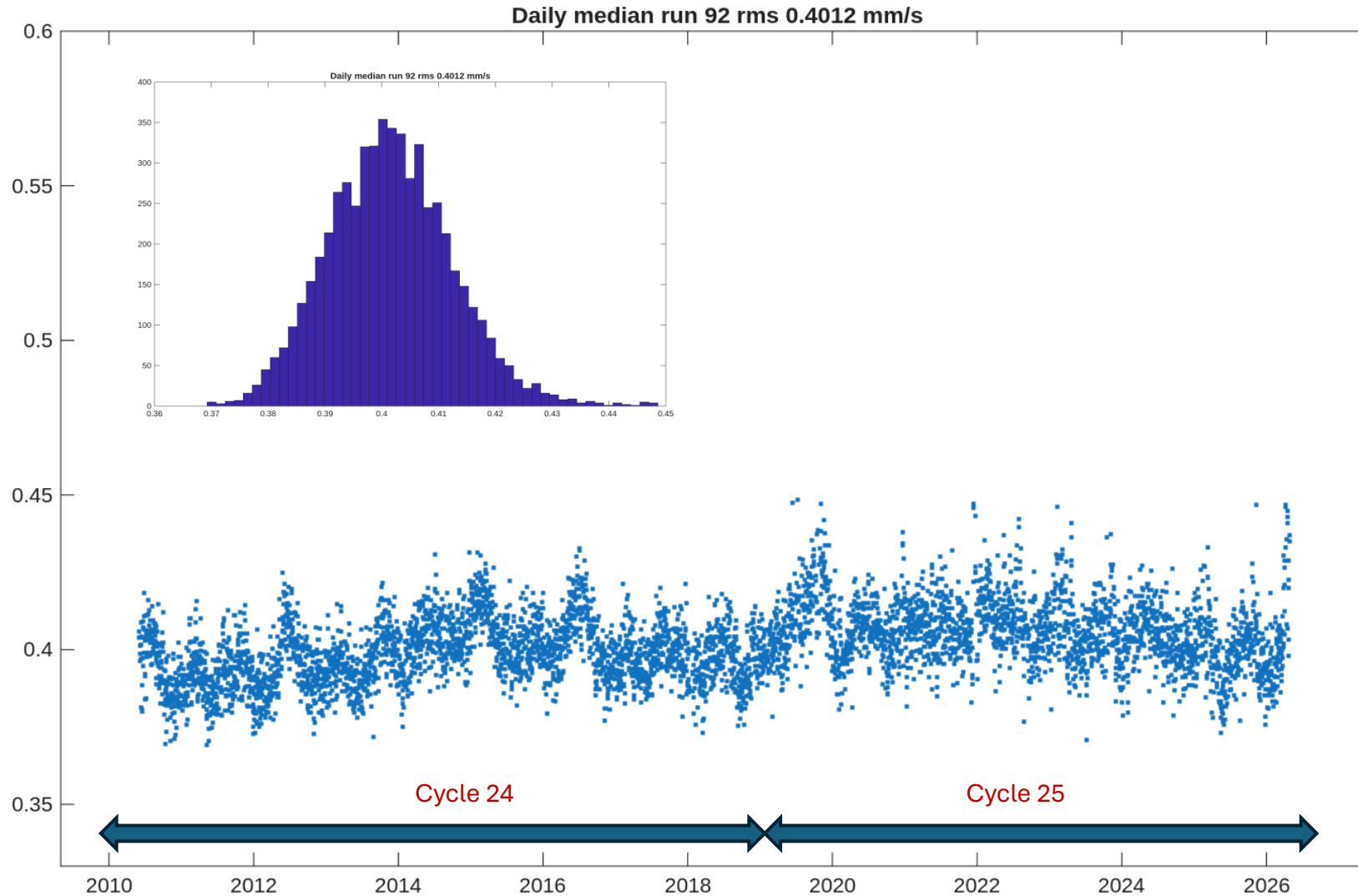
Doppler residuals

No TWS modelled

Suggests that residuals increase towards cycle #25

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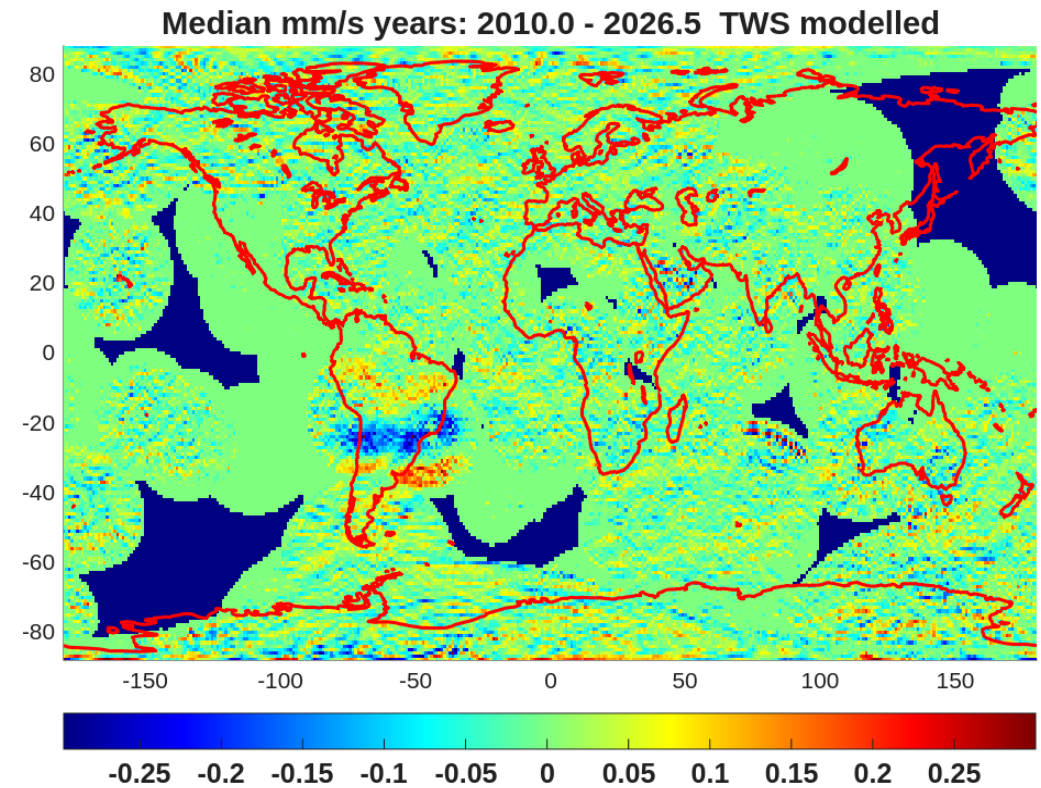
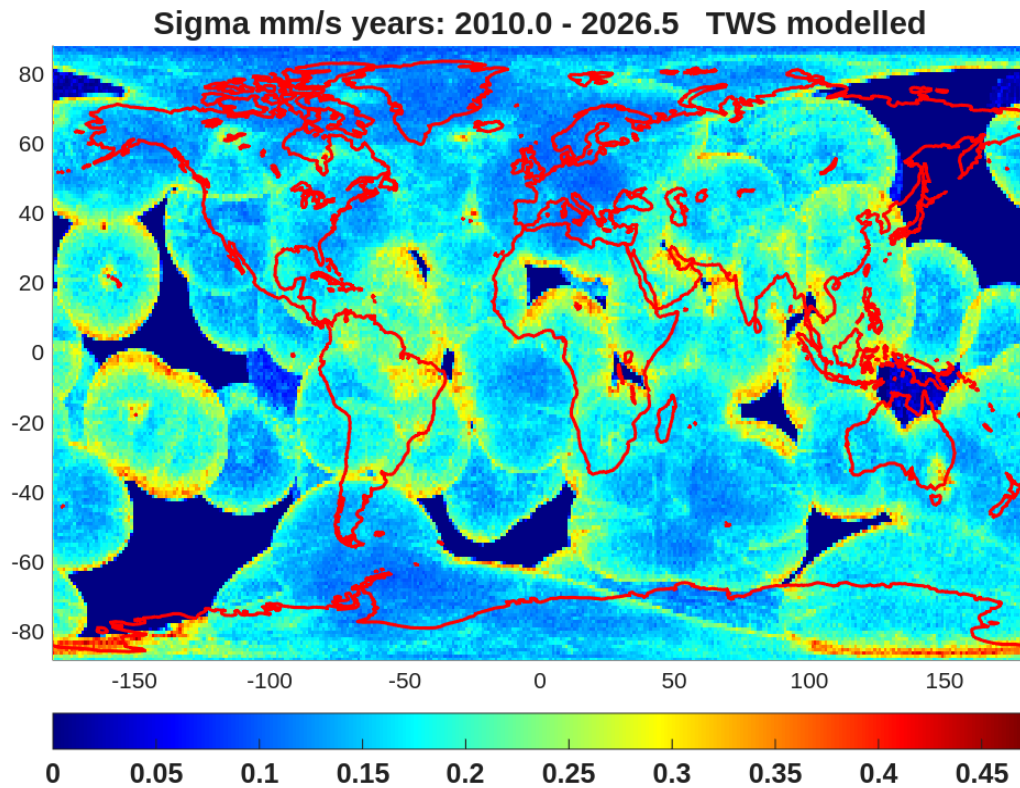
Doppler
residuals

TWS modelled

And the effect disappears
Doppler residuals flatten

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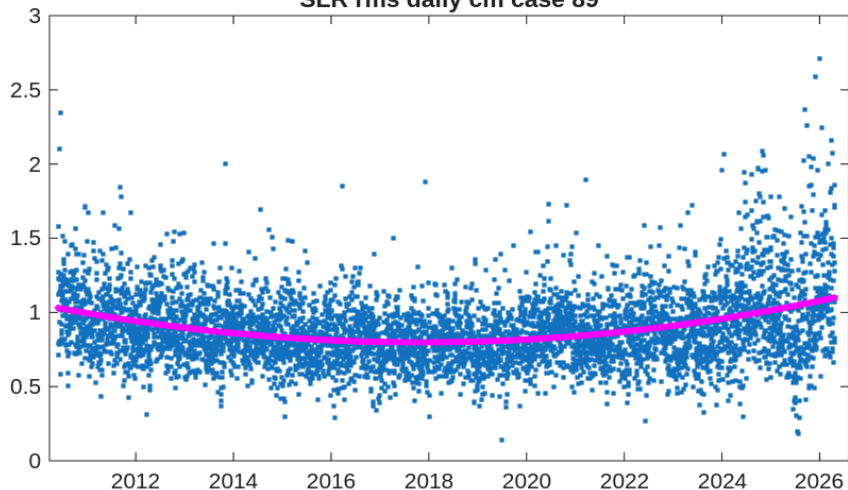
Residual analysis of Doppler measurements



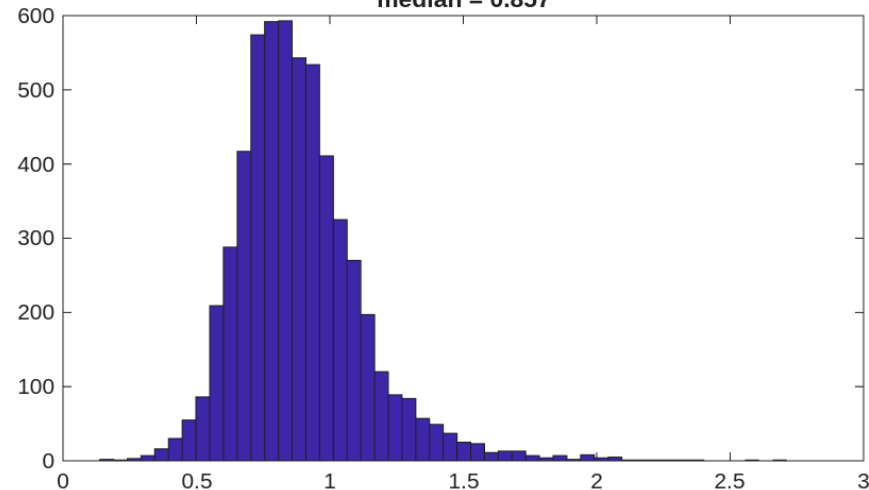
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SLR rms daily cm case 89

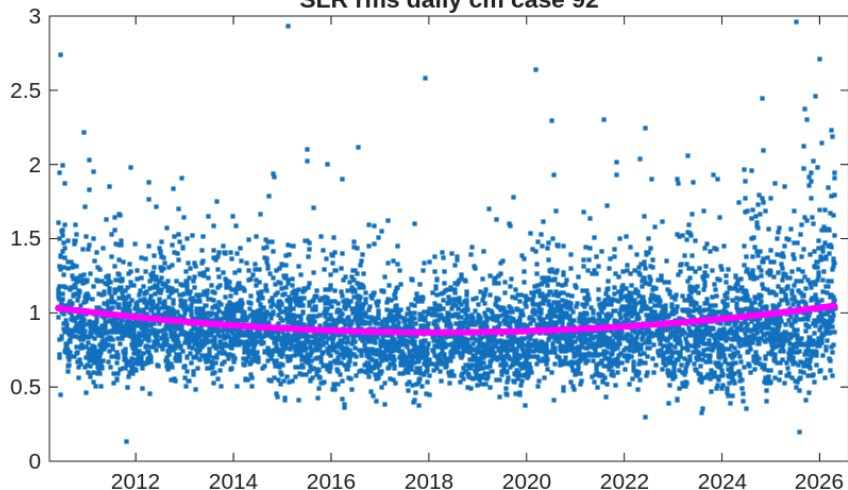


median = 0.857

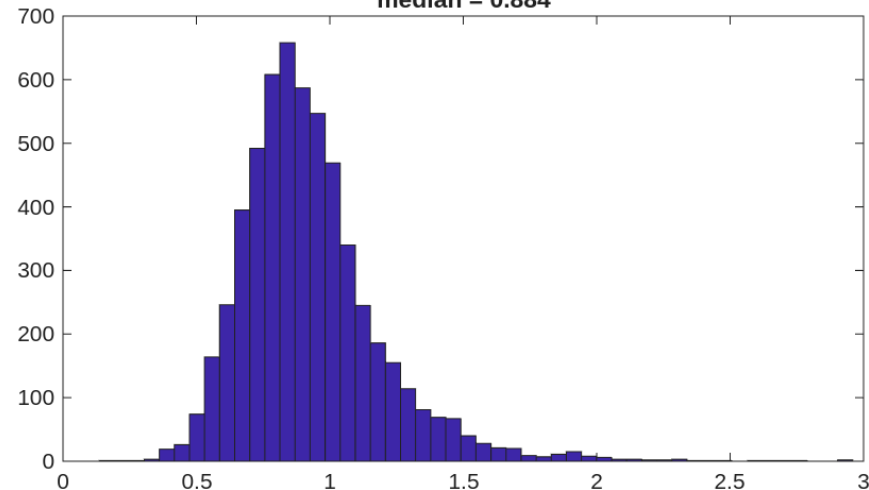


TWS not modelled

SLR rms daily cm case 92



median = 0.884



TWS modelled

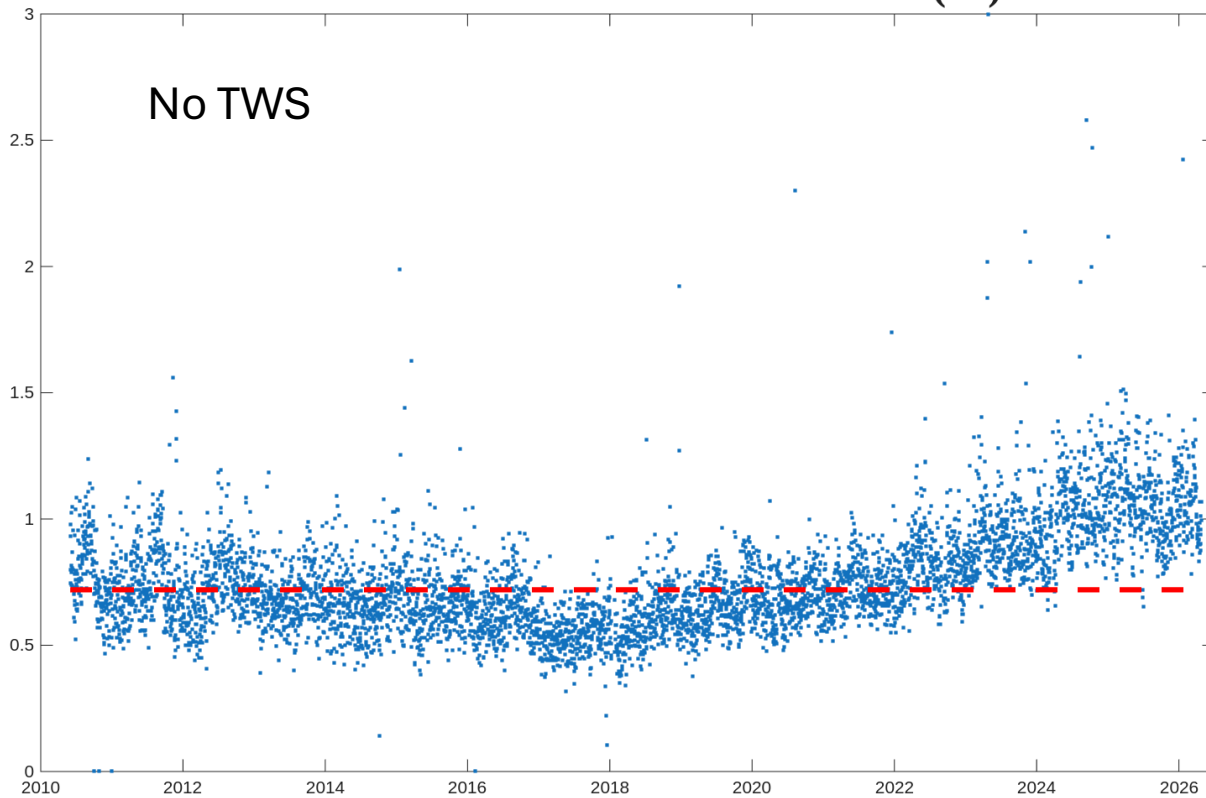
SLR residuals flatten

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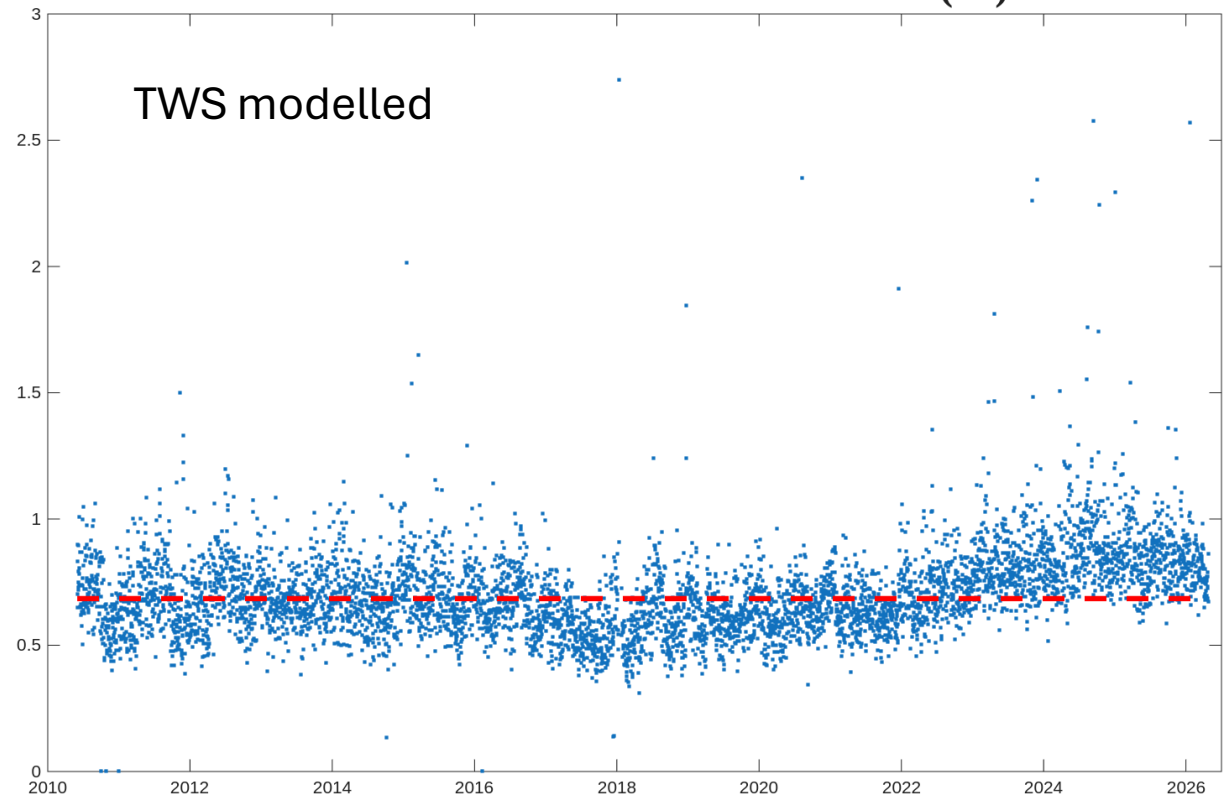
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Radial difference to POE orbit (GDR/E+F)

Radial rms 0.72 cm POE DPOD2020 (89)

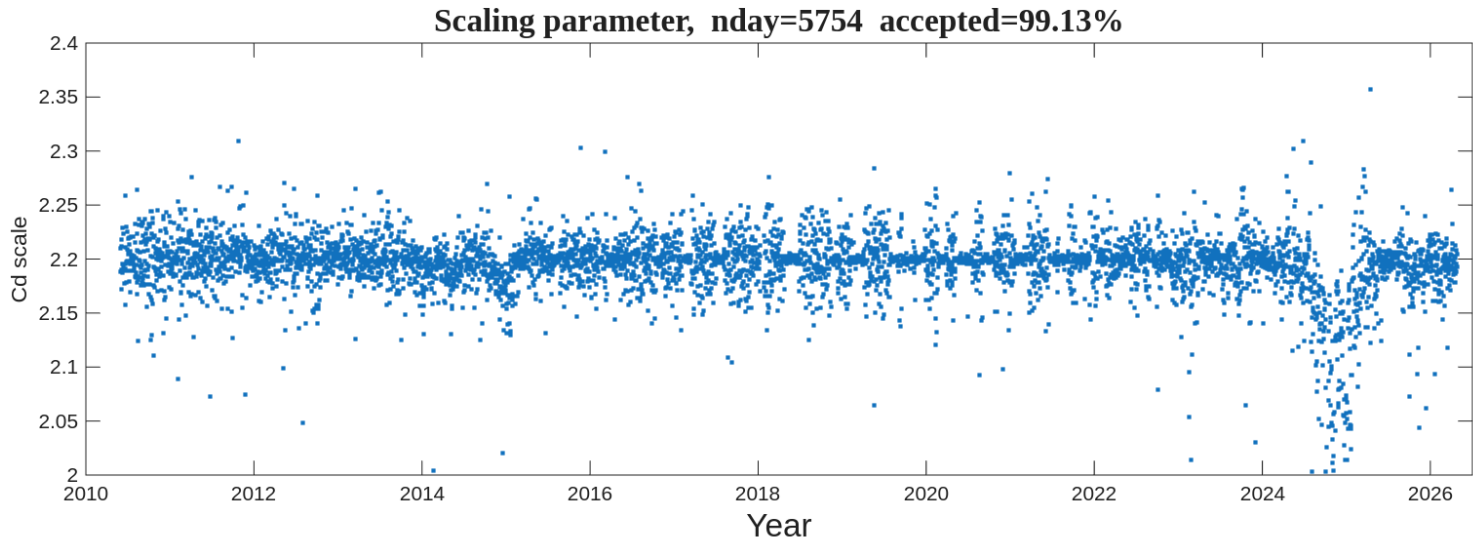


Radial rms 0.69 cm POE DPOD2020 (92)



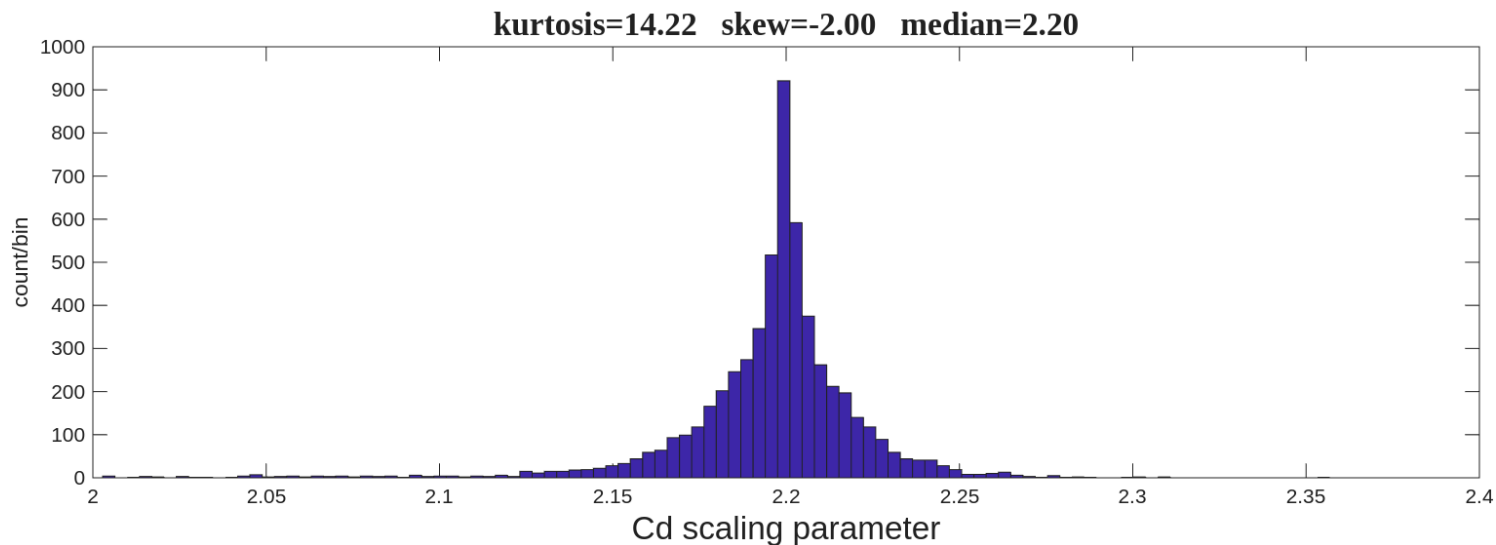
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Solved for Cd scaling over time

Occasional excursion below 2.2 when the SFU is high



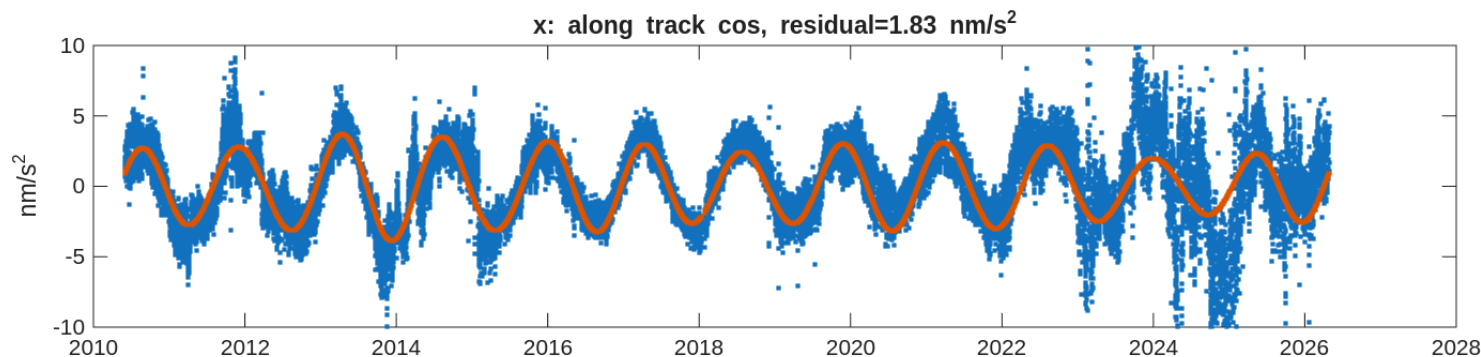
Histogram is leptokurtic

There is more in the tails than in the middle

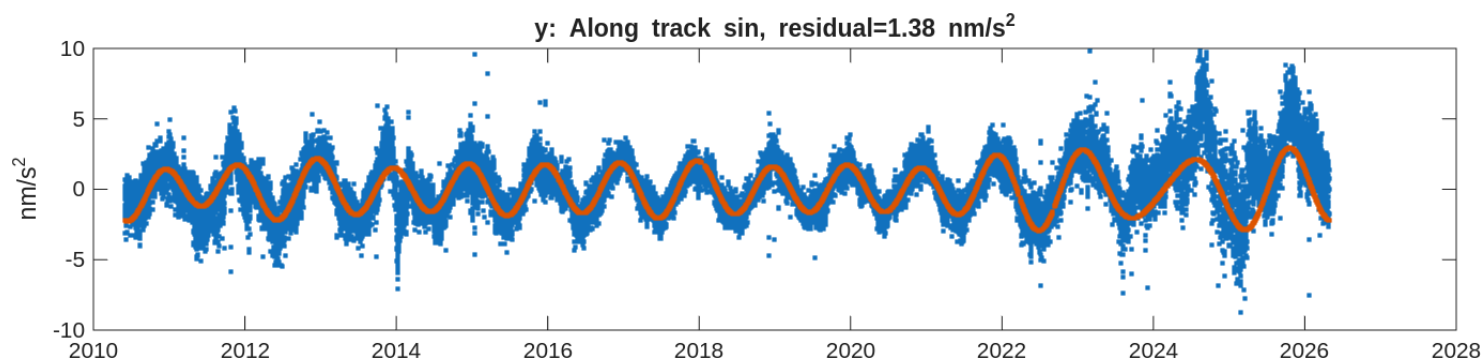
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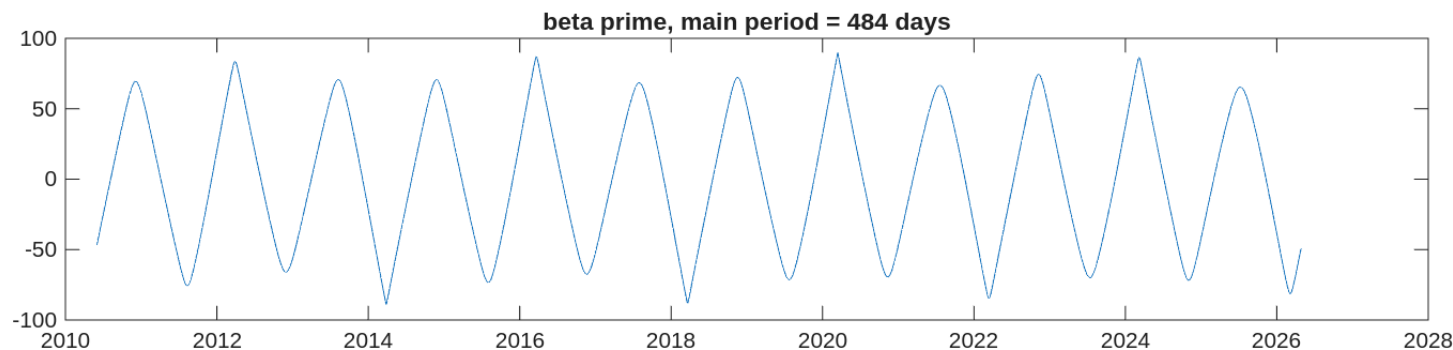
cos



sin



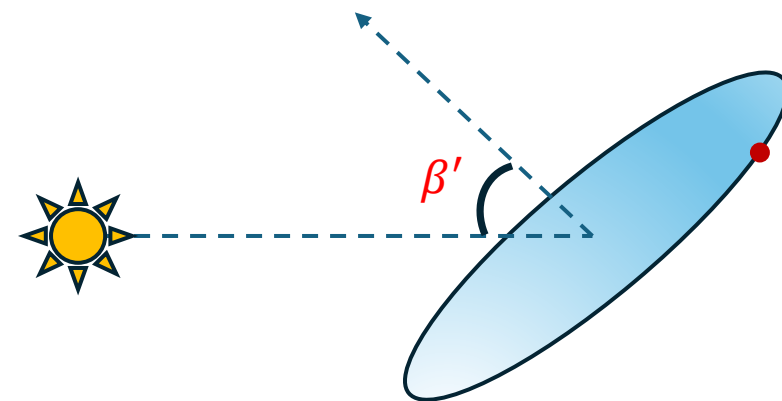
β'



Along track empirical accelerations

Blue : 6 hourly values

Red : harmonic regression model

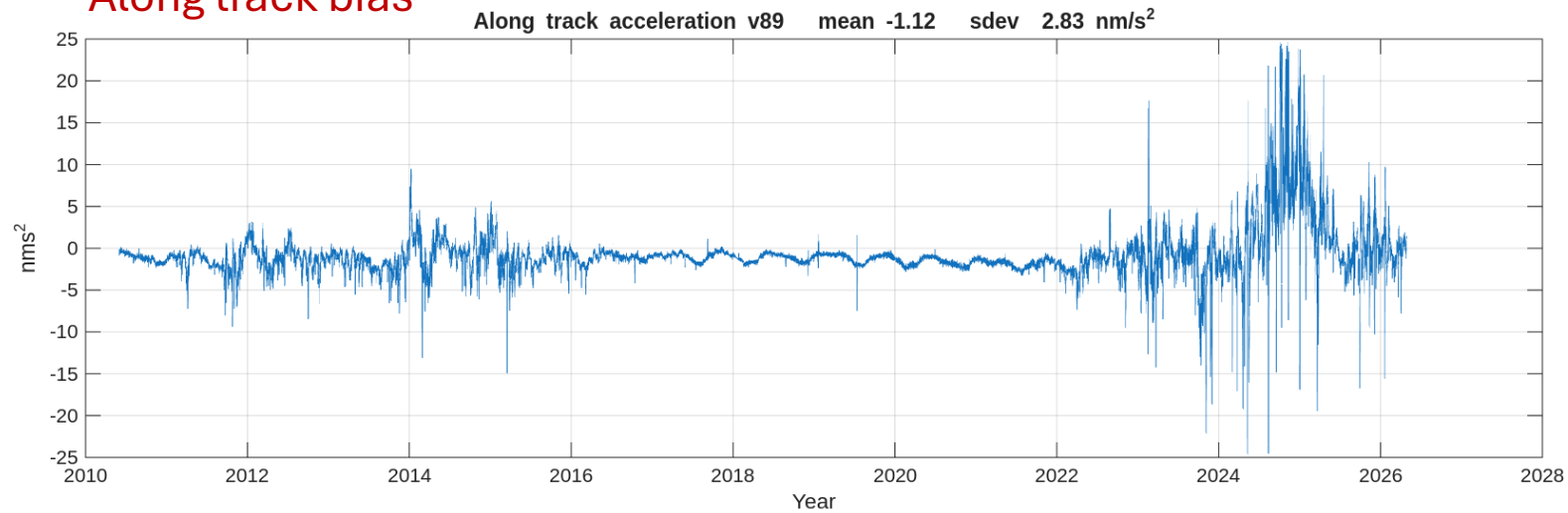


Perhaps we could still improve the panel model, but it won't help you in maxima of the solar cycle

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Along track bias

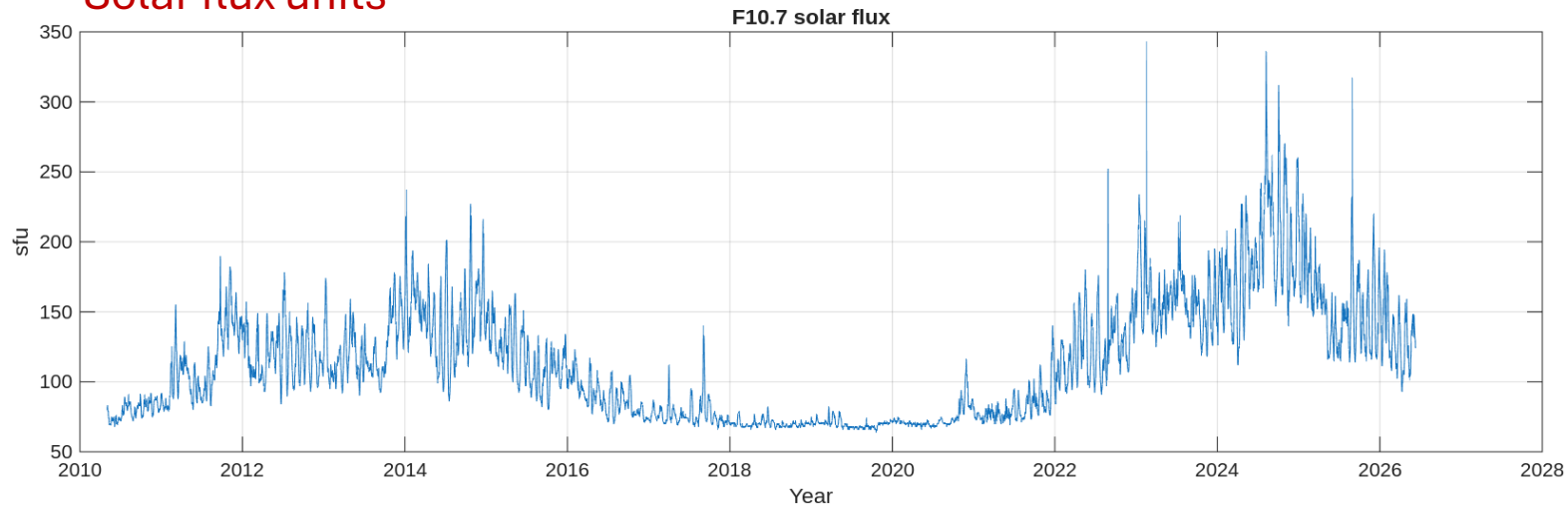


Empiricals

Along track bias significantly correlates to F10.7 variations

Solar cycle 25 is stronger 24

Solar flux units



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Residuals

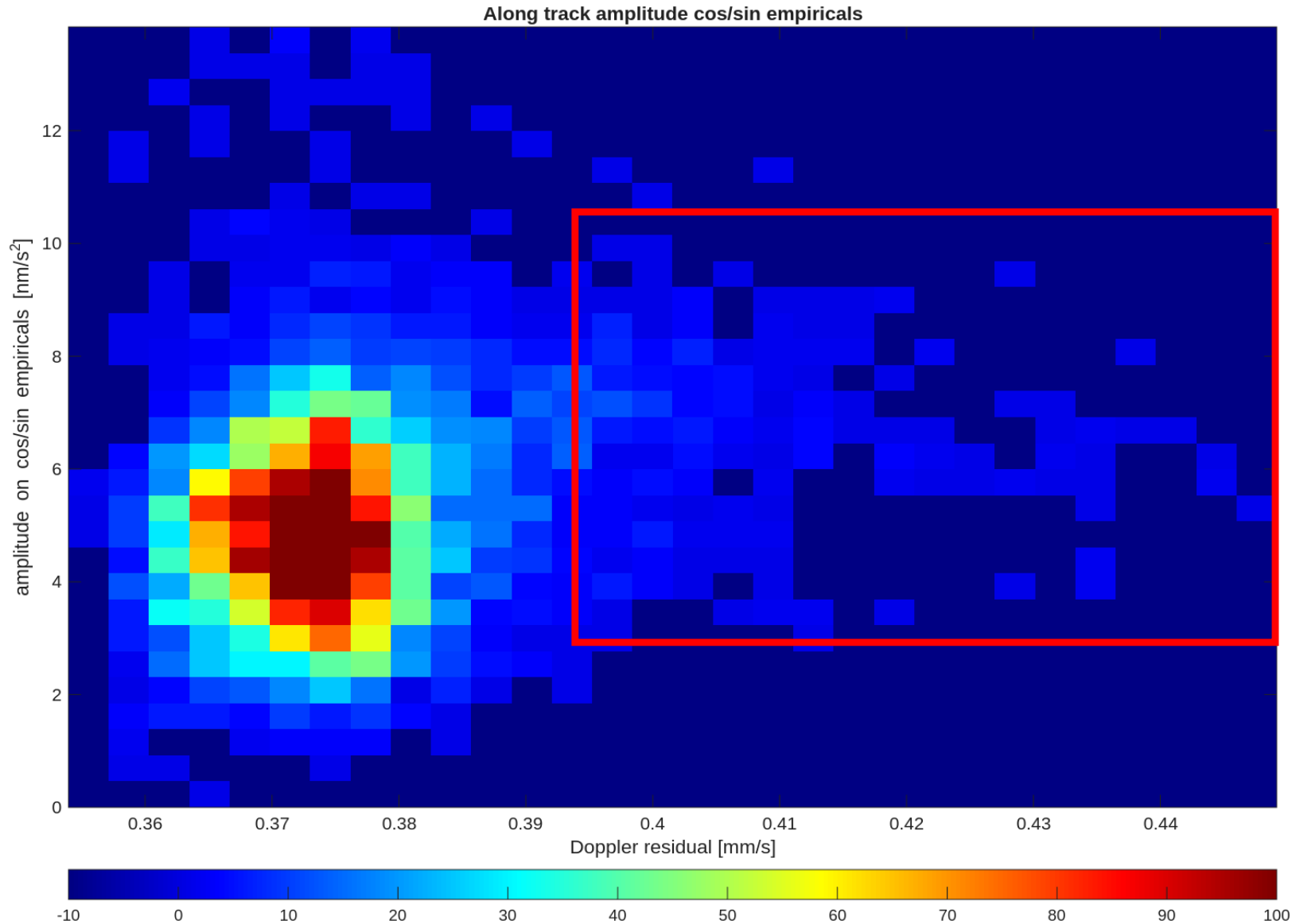
Run	DORIS	Laser	COS	SIN	Bias	Radial POE
	mm/s	cm	nm/s ²	nm/s ²	nm/s ²	cm
No TWS	0.3883	0.857	1.83	1.38	2.83	0.72
TWS	0.4012	0.884	1.69	1.33	2.80	0.69

Adding TWS via GRACE and GRACE-FO

- Empiricals reduce in size,
- Difference to POE orbit decreases
- Tracking residuals slightly increase

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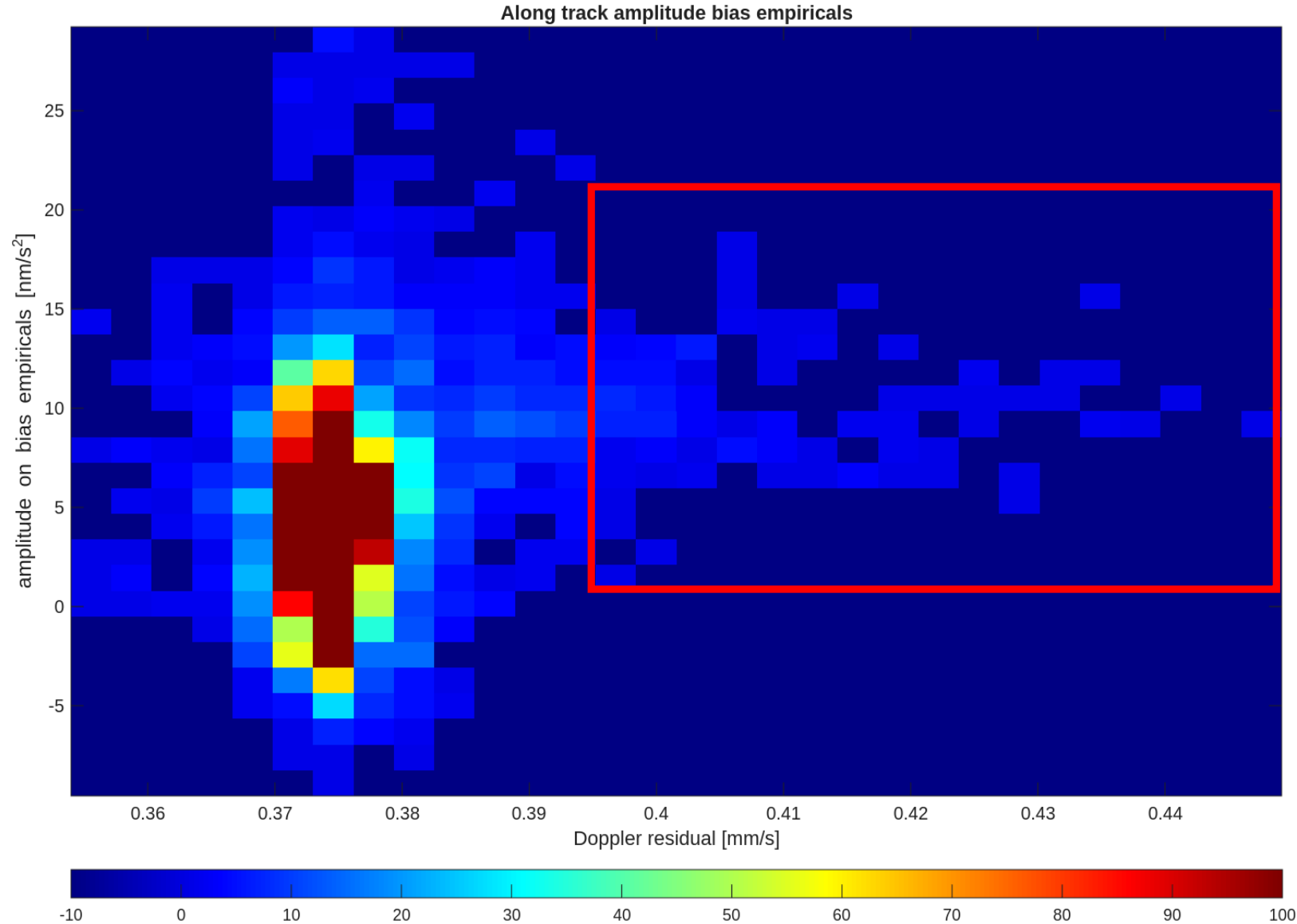


Empirical / Doppler

Along track cos/sin

Larger Doppler residuals
correspond to larger
empiricals

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Empirical / Doppler

Along track bias

Larger Doppler residuals
correspond to larger
Empiricals, same conclusion

Conclusions

- This is the 16th anniversary of a satellite intended for freeboard measurements of sea ice. Precision orbits were not really required, ocean applications followed later.
- Orbits independently reproduced to ≈ 0.40 mm/s and 9 mm in the tracking residuals, radial orbit error < 8 mm for altimetry
- Tendency to deteriorate solar maximum #25,
- In particular 2024-2025 was difficult

References

- Schrama EJO and Visser PNAM (2024) Choices for Temporal Gravity field modeling for Precision Orbit Determination of CryoSat-2, Advances in Space Research, Volume 73, Issue 1, Pages 31-41, [doi: 10.1016/j.asr.2023.11.034](https://doi.org/10.1016/j.asr.2023.11.034)