

Midnight discontinuities in repro3 orbits: what can we learn about solar radiation pressure mismodeling?

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Context & Motivation

GNSS position time series are affected by non-geophysical signals that limit deformation studies at the millimeter level. Among them, draconitic periodic signals [Ray et al., 2008] remain difficult to mitigate. They are largely attributed to solar radiation pressure (SRP) mismodelling, driven by the Sun–Earth–satellite geometry (Figure 1.1).

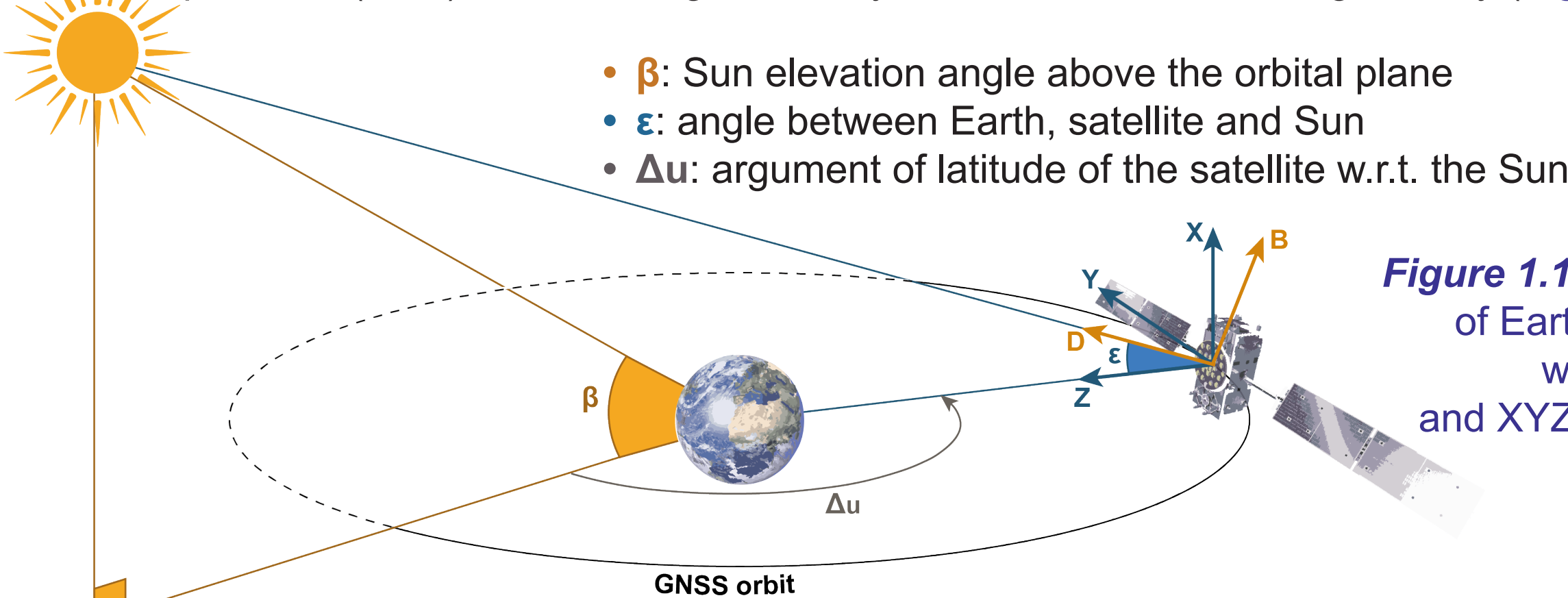


Figure 1.1 - GNSS satellite orbits: illustration of Earth, Satellite and Sun geometry, with DYB (Sun-referenced) and XYZ (body-fixed) orthogonal frames.

Midnight discontinuities (Figures 1.2 and 1.3) in GNSS orbits provide a direct observable of dynamic modeling errors, including SRP-related effects. While this observable is commonly used in individual studies [Sibthorpe et al. 2011, Dahr et al. 2021, Dilssner et al. 2025], a systematic evaluation and comparison across the IGS AC repro3 solutions is lacking.

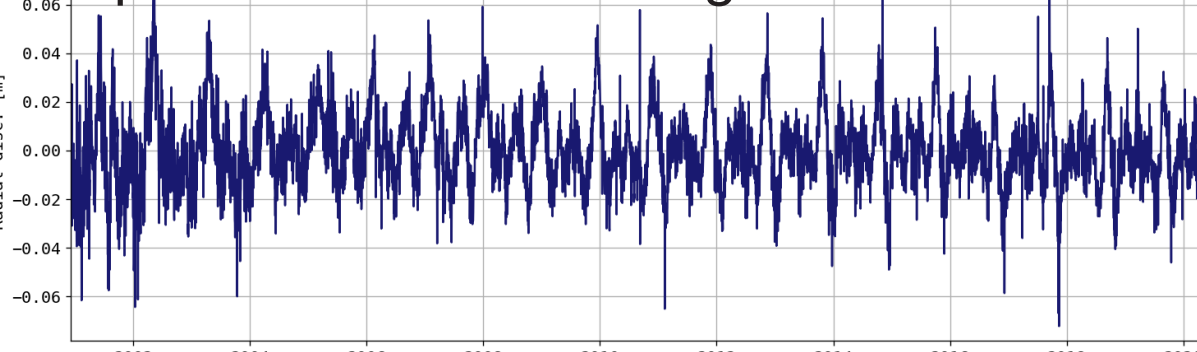
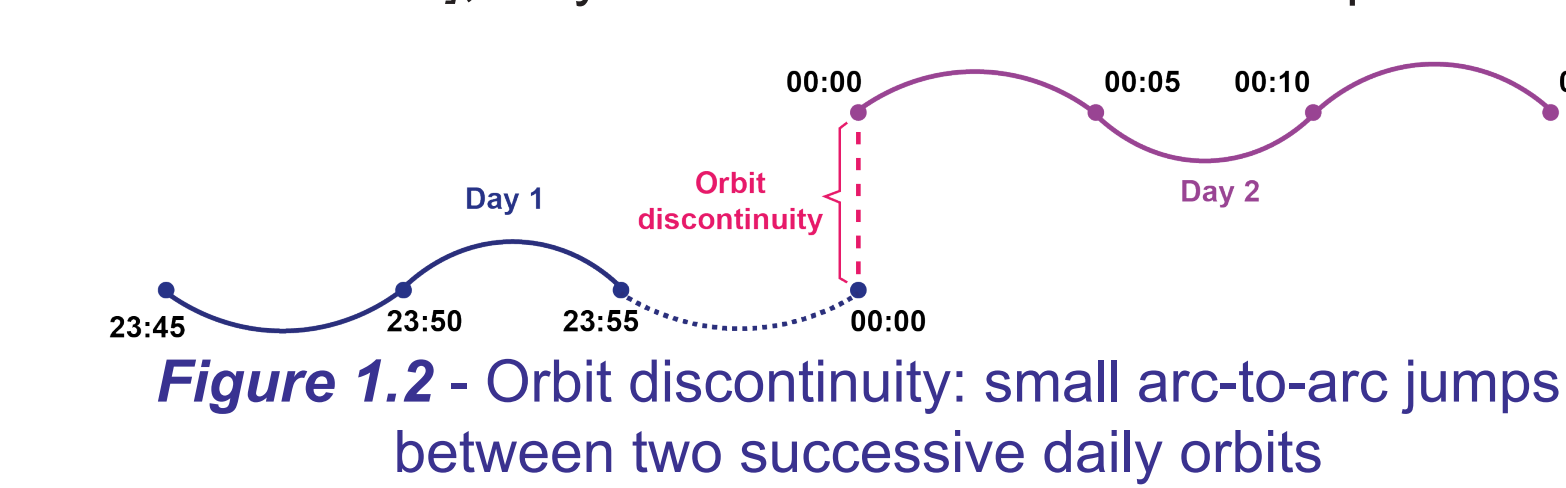


Figure 1.3 - Example of midnight discontinuities time series, radial component [G041 satellite, block GPS-IIR-A, TUG orbits]

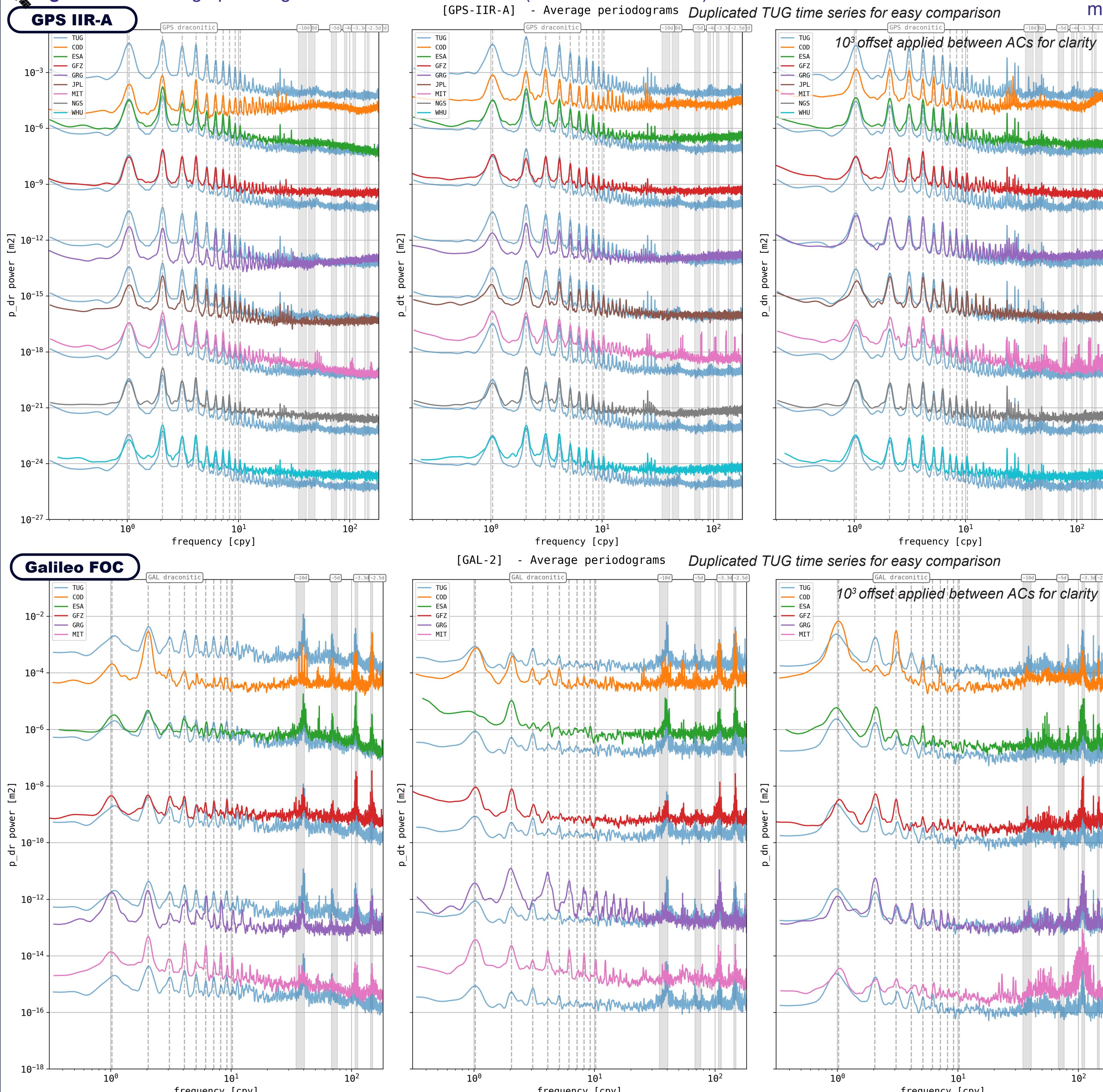
This study investigates what midnight discontinuities in repro3 orbits reveal about SRP mismodeling in the IGS AC repro3 solutions.

Midnight Discontinuities Analysis

An overview of 3D RMS of orbit midnight discontinuities across satellite (SVN) sets and ACs is shown in Figure 3.1. The following examples correspond to the most representative satellite blocks with the largest amount of available data for GPS (IIR-A, 8 satellites) and Galileo (FOC, 24 satellites). For each GNSS block and RTN component:

- Mean periodograms are computed after outlier removal to investigate spectral signatures (Figure 3.2)
- $\beta / \Delta u$ maps are used to analyze the dependence of midnight discontinuities on satellite–Sun geometry (Figure 3.3)

Figure 3.2 - Average periodograms of orbit discontinuities (corrected for outliers) in the RTN frame.



Spectral signatures of midnight discontinuities

- GPS**
- Draconitic periods and harmonics are consistently observed across all ACs.
 - Residual tidal-related signatures (~14 d) are also identified.

- Galileo**
- Draconitic signatures and harmonics across all ACs
 - Aliasing effects are particularly visible around the ~10 d and 3.3 d periods.

Orbit data & Processing

AC	Temporal res. (min)	Midnight value?	Constellation	Arc length (h)	A priori	SRP model	Stochastic param.
COD	5	✓	G,R,E	72	Box-wing only for E	(7 par) D0, Y0, B0, B1C, B1S, D2C, D2S	In R, T, N at orbit midnight
ESA	5	✓	G,R,E	24	Box-wing	(7 par) D0, Y0, B0, + B1C, B1S + Along-track 1C/1S	x
GFZ	5	x	G,R,E	24	x	(9 par) D0, Y0, B0, B1C, B1S, D2C, D2S, D4C, D4S	In R, T, N at orbit noon
GRG	5	x	G,R,E	30	Box-wing	(7 par) D0, Y0, B0, B1C, B1S, D2C, D2S	In R, T, N at orbit noon
JPL	15	x	G	30	GSPM13b	Solar Scale (D0)	x
MIT	15	x	G,E	24	Direct only	(9 par-satellite-week dependent) D0, Y0, B0, B1C, B1S, D2C, D2S, D4C, D4S	x
NGS	15	x	G	?	?	?	?
TUG	5	✓	G,R,E	24	Box-wing	(7 par) D0, Y0, B0, B1C, B1S, D2C, D2S	In R, T, N at orbit midnight
WHU	15	x	G,R	24	x	(7 par) D0, Y0, B0, B1C, B1S, D2C, D2S	x

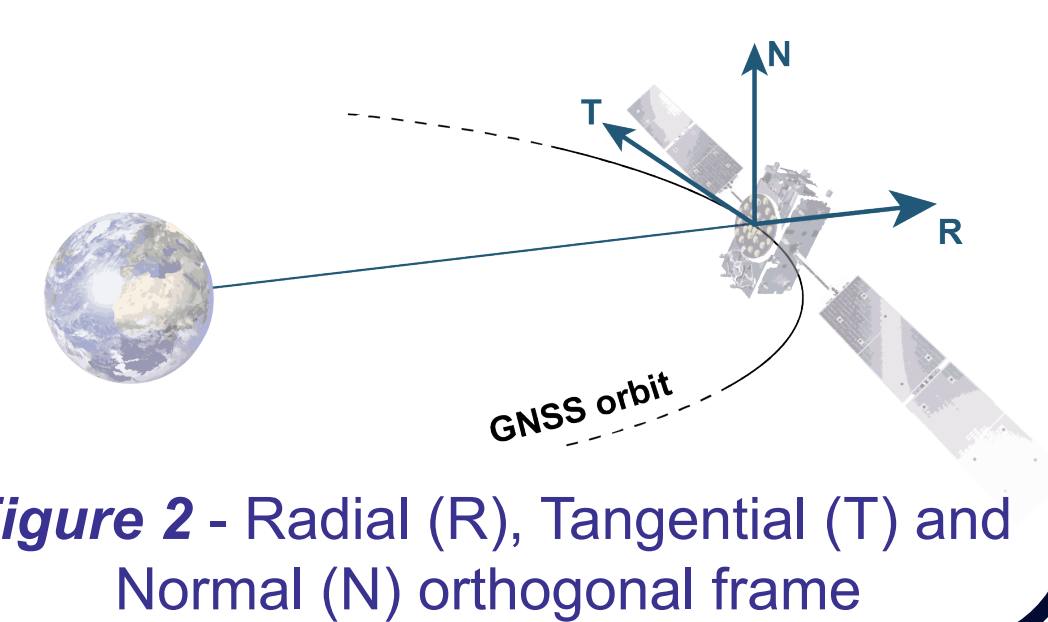
Table 1 - Summary of SP3 file characteristics and orbit modelling strategies of IGS repro3 ACs, detailed in Zajdel et al. 2023. * No public details are available for the NGS processing strategy. All D-, Y-, and B-parameters refer to the ECOM model formulation [Beutler et al. 1994]. GSPM13 model detailed in Sibois et al. 2014.

Data:

- Repro3 final orbit products from 9 IGS ACs (Table 1)
- Time span: 2000–2022
- Midnight values not directly available for 6 ACs

Analysis workflow:

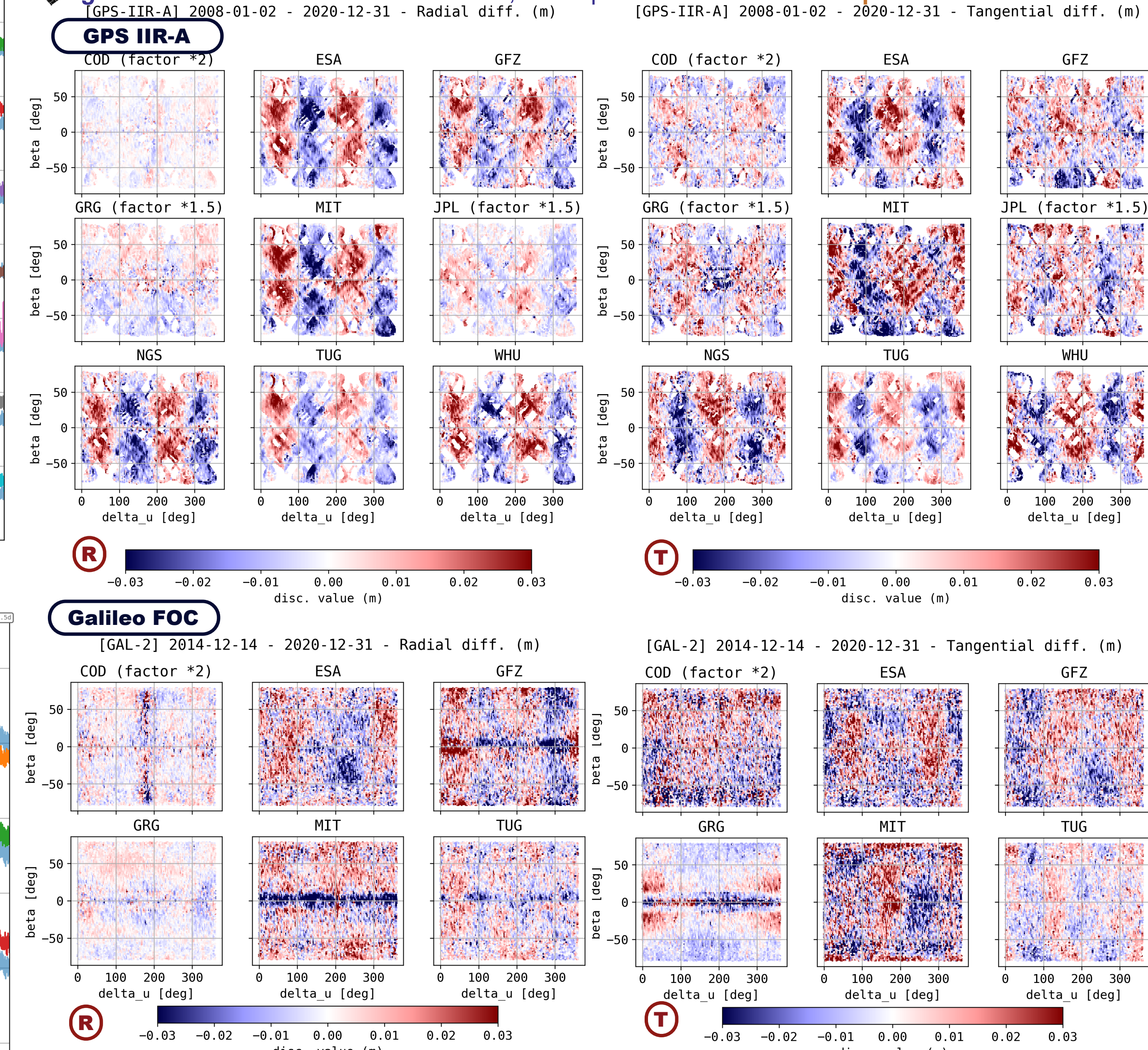
1. Perform orbit fitting using GINS software [Marty et al. 2011, Ait-Lakbir et al. 2023]
2. Compute orbit discontinuities in the RTN frame (Figure 2)
3. Investigate spectral characteristics and satellite–Sun geometry dependence for each GNSS block



QR code to access the complete set of figures for all satellite blocks from the final repro3 orbit products

Figure 3.1 – 3D RMS of midnight discontinuities per satellite (SVN) and ACs

Figure 3.3 - Orbit discontinuities in the R, T components as a function of β and Δu



Dependence on satellite–Sun geometry

- GPS: Column-like structures appear in the β and Δu maps, indicating a dependence of orbit discontinuities on the Sun–satellite geometry.
- Galileo: larger discontinuity amplitudes are observed during eclipse seasons particularly for MIT (R) and GRG (T)

AC-dependent behaviours

- ACs using different orbit arc lengths (e.g., 24 h vs. 30 h) are difficult to compare directly. Longer orbit arcs smooth midnight discontinuities, reducing their apparent amplitude. Compared to other ACs using 24 h arcs, TUG solutions appear to exhibit lower-amplitude midnight discontinuities (Figure 3.1)
- While the main spectral signatures are common to all ACs, some localized differences in peak amplitudes are observed between processing strategies, e.g. much larger 3.3d signals in MIT's Galileo normal orbit discontinuities (Figure 3.2)

Conclusions & Perspectives

- Midnight discontinuities contain clear signatures dependent on satellite–Sun geometry, supporting their interpretation as residual SRP-related effects. They can therefore be used as a diagnostic to reveal both common SRP mismodelling signatures across all ACs and differences between processing strategies.
- The direct availability of midnight orbit values is essential for a robust characterization of these discontinuities.
- Orbit arc configuration significantly affects midnight discontinuity amplitudes and must therefore be considered when interpreting inter-AC differences.
- These analyses provide both an initial state-of-the-art assessment of repro3 midnight discontinuities and a reference framework for evaluating future SRP modelling approaches (e.g. «RnR model» developed in Dilssner et al. 2025)

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