

Toward a standardized GNSS satellite attitude modeling framework

- A joint effort within the IGS SVOD Committee

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Key Messages



I: [Precise](#) and [consistent](#) GNSS satellite attitudes are essential

II: Modern GNSS satellites require diverse attitude [models](#) that are not always implemented consistently

III: Several special cases in [rate-limited modeling](#) require robust handling

- β -sign changes during an event
- First-epoch already inside an event
- GPS Block II/IIA yaw-rate handling

IV: Towards a standardized attitude modeling framework: [do_gnss_attitude](#)

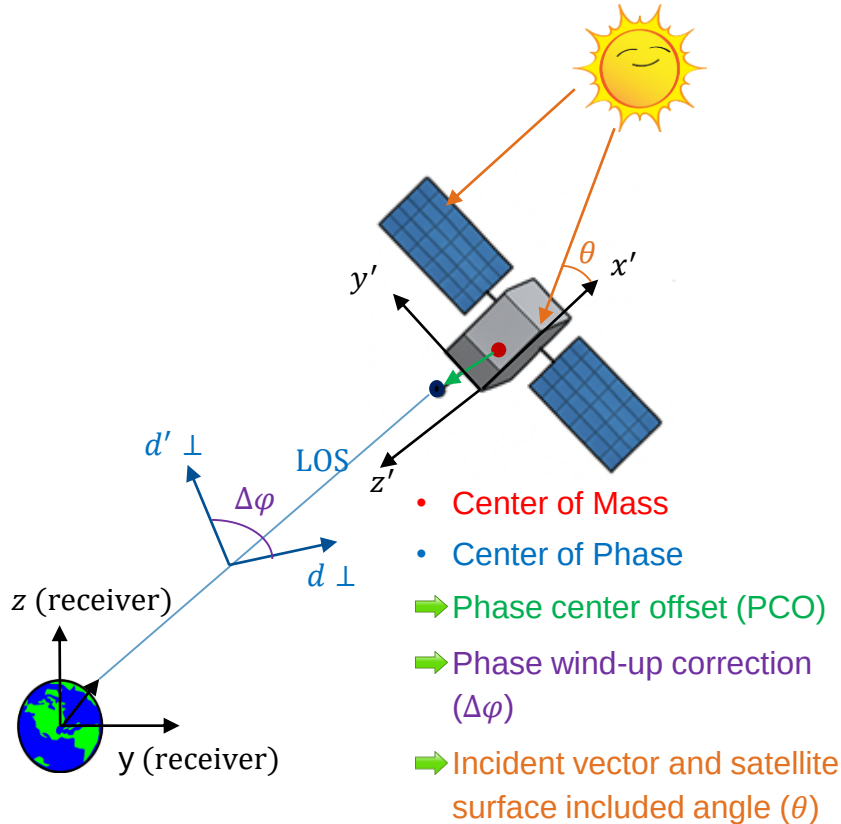
1. Introduction and motivation

Attitude mismodeling propagates into:

- PCO correction
- Phase wind-up correction
- Radiation pressure macro (surface) modeling

Leads to inconsistencies:

- ➡ between satellite products from IGS ACs
- ➡ for the clock/bias combination
- ➡ between product generation and PPP-AR users



2. GNSS satellite attitude – fundamental modes

Nominal yaw steering (YS)

- Navigation antenna (Z+) points to Earth
- Solar panels face Sun
- Law: $\psi = \text{atan2}(-\tan\beta, \sin\mu)$

Orbit normal (ON)

- Satellite body aligned with the orbital frame
- Solar panels remain perpendicular to the orbital plane

Rate-limited yaw steering for low β

- Shadow crossing
- Midnight and noon turns

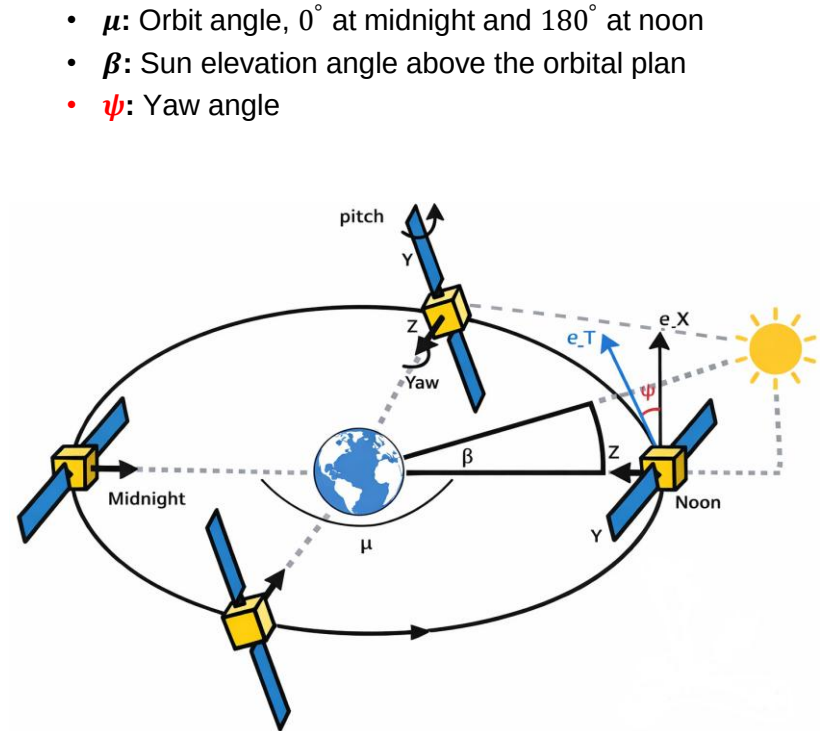
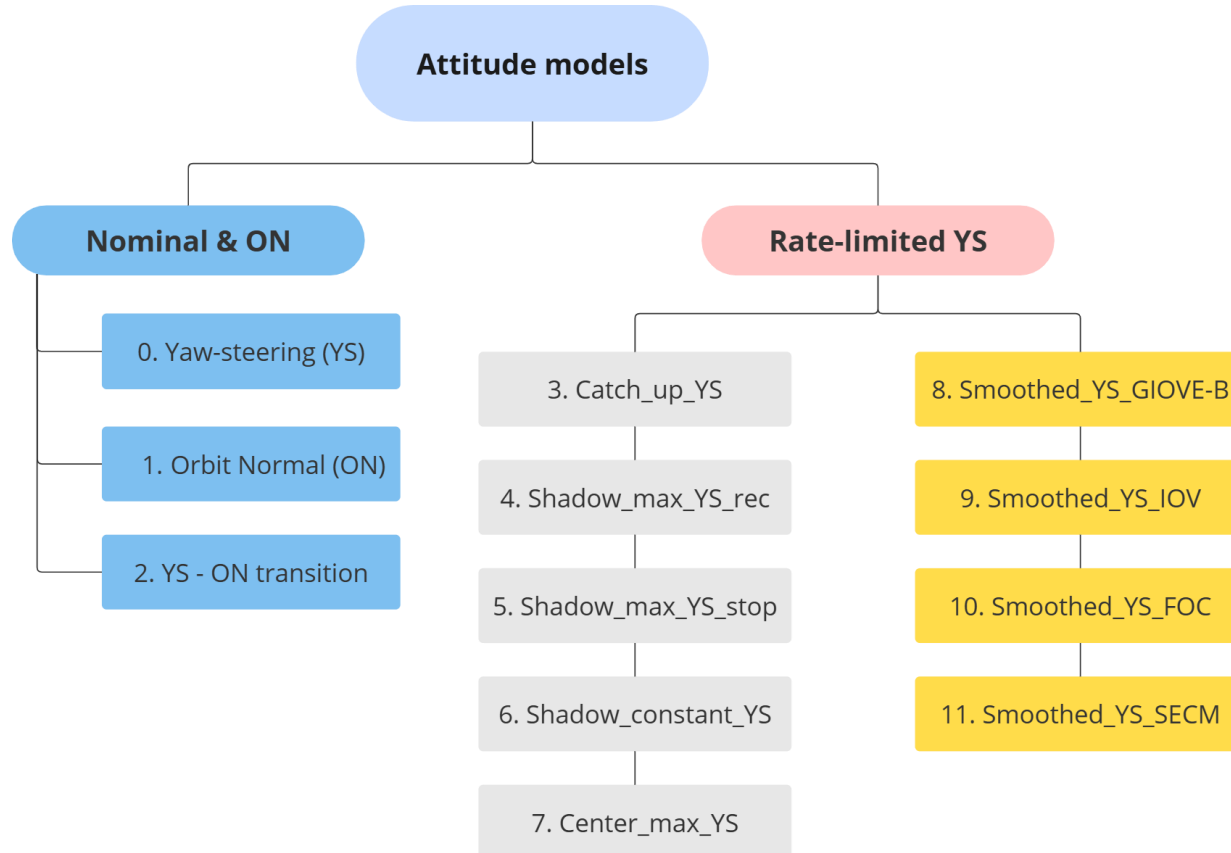


Image reproduced from Strasser et al. (2021) and Montenbruck et al. (2015)

2. GNSS satellite attitude – available attitude models



Naming convention follows
Strasser et al (2021)

2. GNSS satellite attitude – satellites-specific configuration

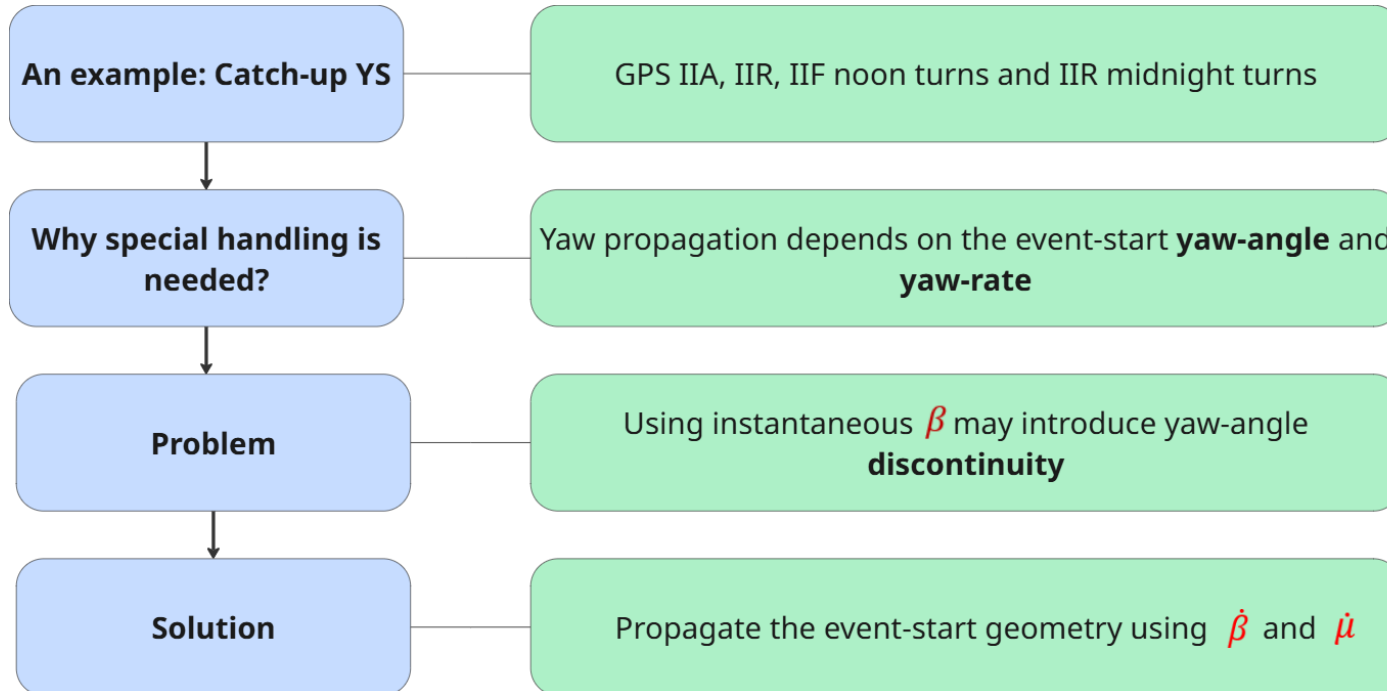
Sat. block	Nominal & Orbit normal	Rate-limited	Reference
GPS II/IIA	0	3, 4	Bar-Sever 1996
GPS IIR	0	3	Kouba 2009
GPS IIF	0	3, 6	Dilssner 2010, Kuang et al 2017
GPS III	0	9	Montenbruck et al 2026
GLONASS-M	0	6, 7	Dilssner et al 2011
GLONASS-K	0	7	Dilssner et al 2024, Steigenberger et al 2024
Galileo-IOV	0	9	GSC
Galileo-FOC	0	10	GSC
BDS-2 IGSO/MEO	2	8	Dai et al 2015, Dilssner et al 2018
BDS-3 CAST	0	10	Wang et al 2018
BDS-3 SECM	0	11	Lin et al (2018)
QZSS IGSO/MEO	0, 2	7	Cabinet office
All GEO	1		Montenbruck et al 2015

Modern GNSS constellations require dedicated attitude implementations

0. Yaw-steering (YS)
1. Orbit-Normal (ON)
2. YS-ON transition
3. Catch_up_YS
4. Shadow_max_YS_recovery
5. Shadow_max_YS_stop
6. Shadow_constant_YS
7. Center_max_YS
8. Smoothed_YS_GIOVE-B
9. Smoothed_YS_IOV
10. Smoothed_YS_FOC
11. Smoothed_YS_SECM

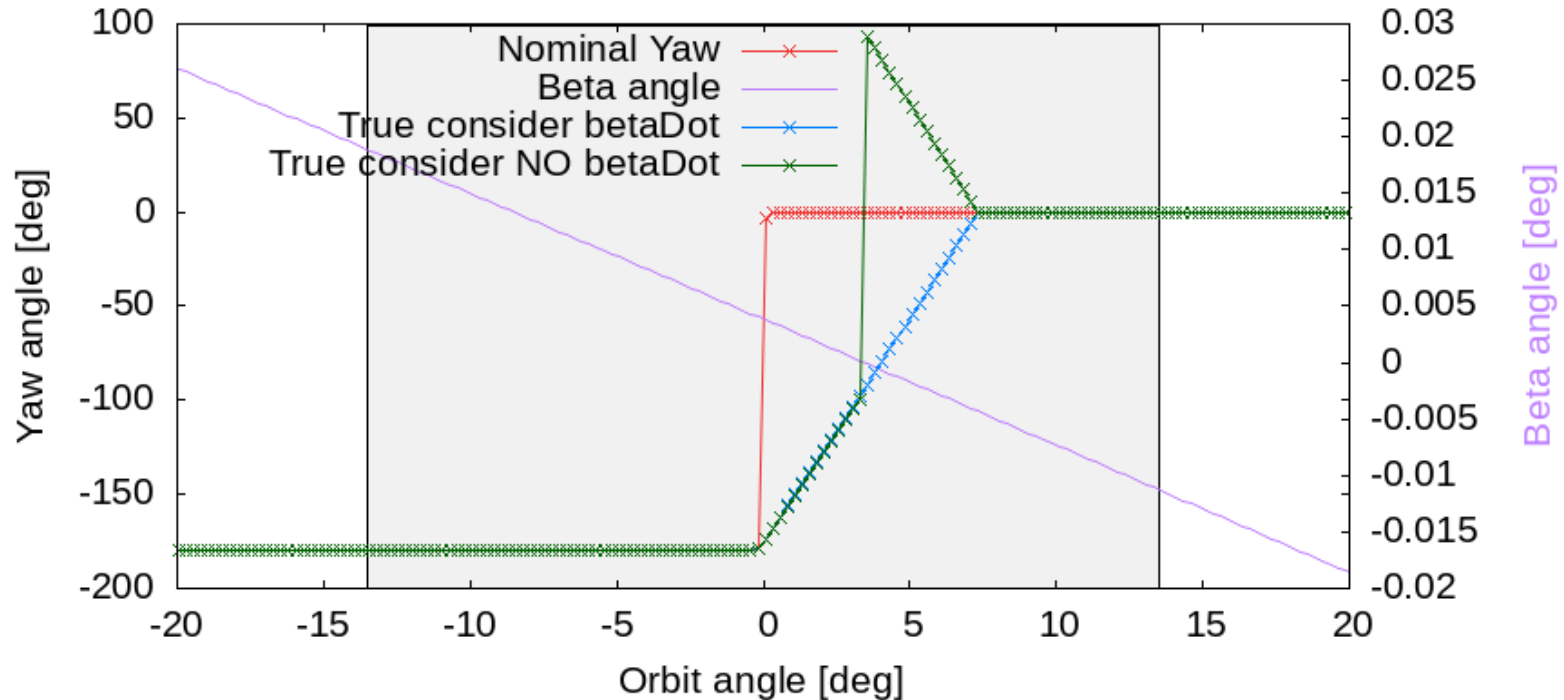
3. Special cases in rate-limited events

β -sign changes during an event



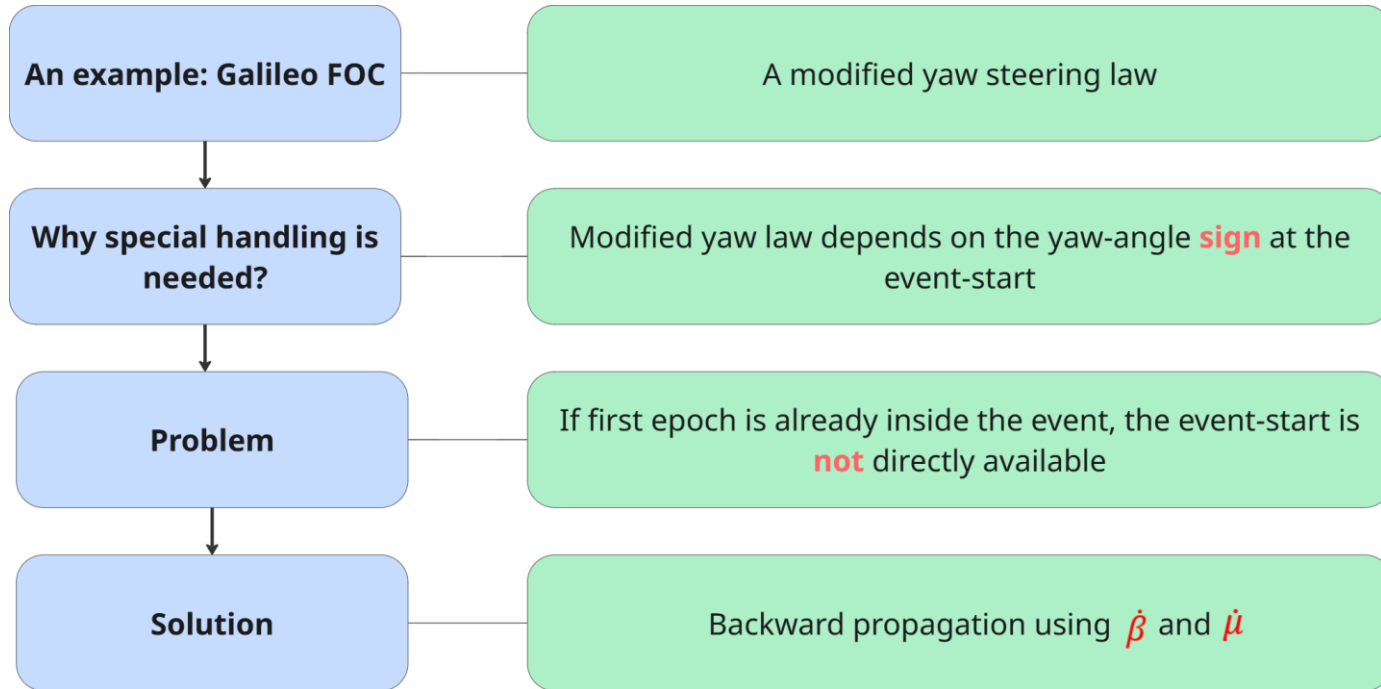
3. Special cases in rate-limited events

β -sign changes during an event



3. Special cases in rate-limited events

First-epoch already in an event



3. Special cases in rate-limited events

GPS Block II/IIA yaw-rate handling

JPL repro2

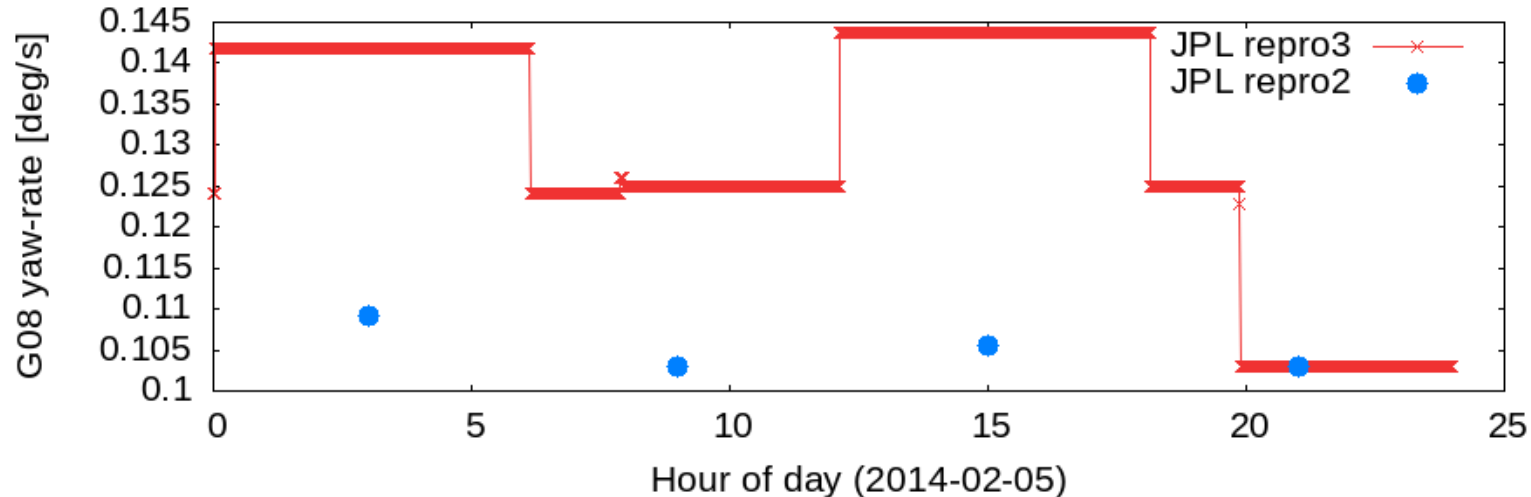
- Piece-wise constant
- Update every 6 hours

or

JPL repro3

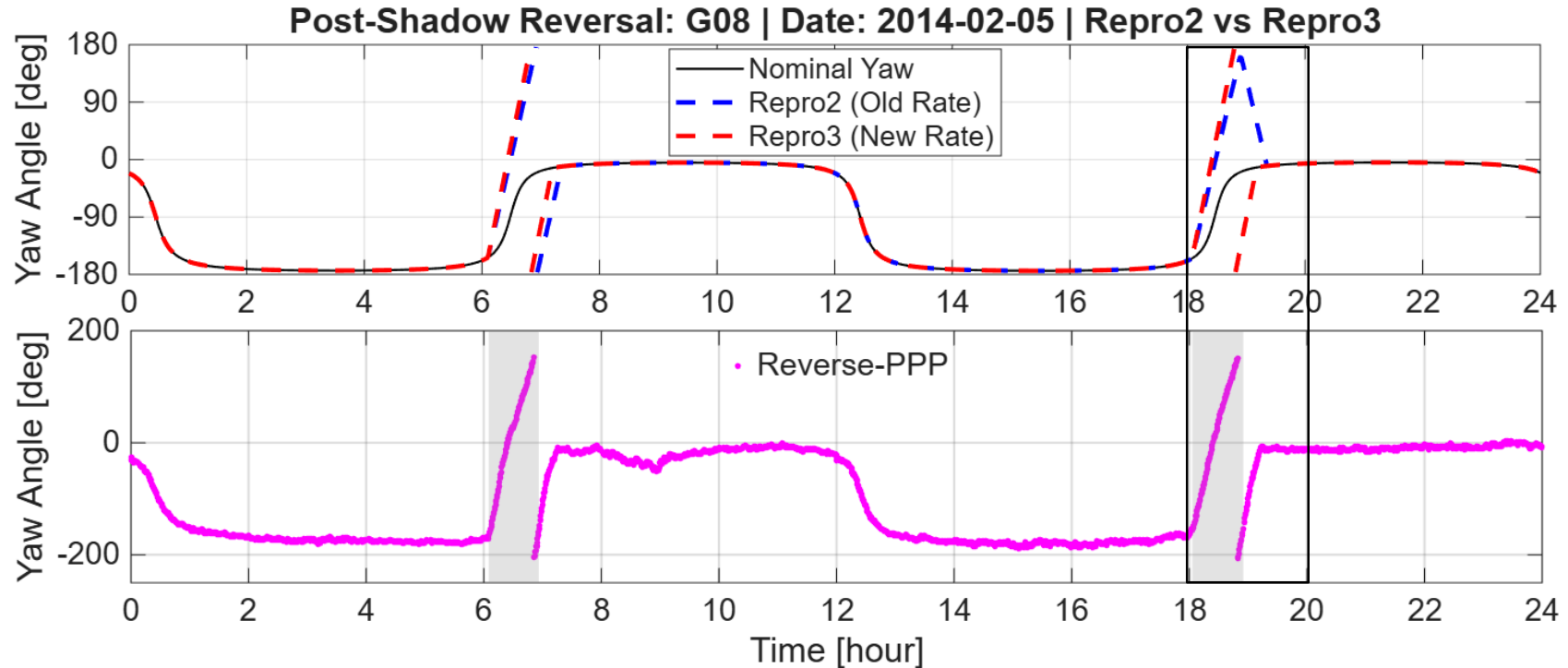
- Epoch-wise
- Constraint to a priori values

↩ May **reverse** the post-shadow recovery direction



3. Special cases in rate-limited events

GPS Block II/IIA yaw-rate handling



4. The *do_gnss_attitude* framework and outlook

A reference implementation within the IGS SVOD Committee

- Supports currently available GNSS satellite attitude models
- Transparent and reproducible reference implementation
- Designed for both IGS analysis centers and end users
- Continuously maintained and updated for new satellites and attitude models



4. The *do_gnss_attitude* framework and outlook

Current status

- A draft version of the *do_gnss_attitude* program is now available
- First-round validation results show good consistency across independent software packages
- Dedicated validation campaigns are ongoing for special cases in rate-limited events
- Additional reverse-PPP analysis for GPS Block IIA satellites is ongoing

Future plans

- Joint journal publication
- Public GitHub repository
- Maintained and updated by the IGS SVOD Committee