Sub-daily Earth rotation parameters from GNSS and combined GNSS-SLR solutions

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IAU Commission 19, Scientific Meeting

Beijing, 30. August 2012

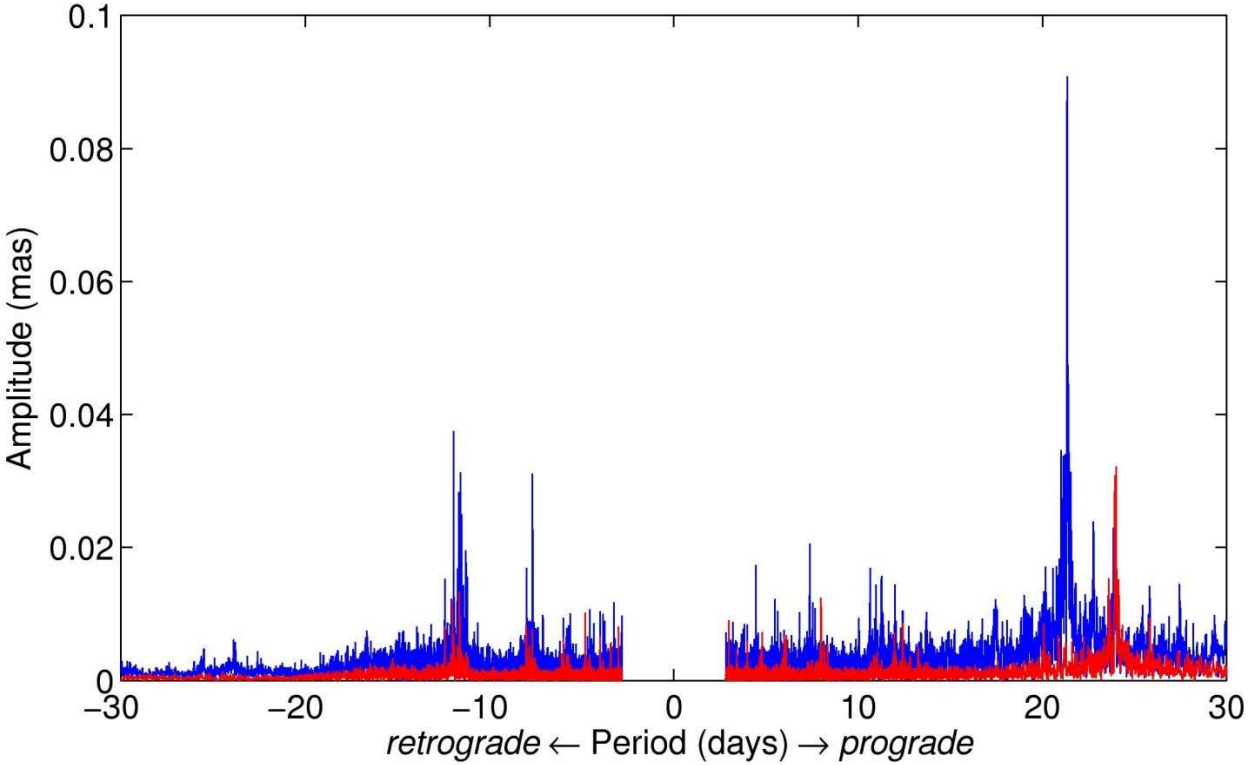
Overview

- Orbit characteristics and artefacts in polar motion time series:
  - GPS / GLONASS orbits
  - LAGEOS orbit
- Handling of the correlation between PM and orbits:
  - Blocking a retrograde-diurnal signal in PM
  - Introduce orbits from 24-h ERP solution
- Results of GNSS, SLR and combined solutions

GNSS-specific artefacts

Many spectral lines are different for GPS and GLONASS

⇒ Most likely system-specific artefacts



GLONASS

GPS

Meindl et al.: ***Processing Batch length in GNSS data analysis: Impact on daily and subdaily Earth rotation parameters.*** Presented at EGU 2012

Theory

- Any 3-dimensional rotation is described by **3 angles**
- Earth orientation is conventionally described by **5 angles** (polar motion x/y, UT1-UTC, nutation $\Delta\varepsilon/\Delta\psi$)
  - Angles are not independent
  - Correlation between nutation and a retrograde-diurnal signal in polar motion (PM)

Remark: Nutation is fixed in the GNSS/SLR solutions presented hereafter $\Rightarrow$ Correlation avoided

Theory: Orbits and sub-daily ERPs

- Transformation inertial – terrestrial with **ERPs**:

$$\mathbf{R}_3(-\theta) \cdot \mathbf{R}_1(y) \cdot \mathbf{R}_2(x)$$

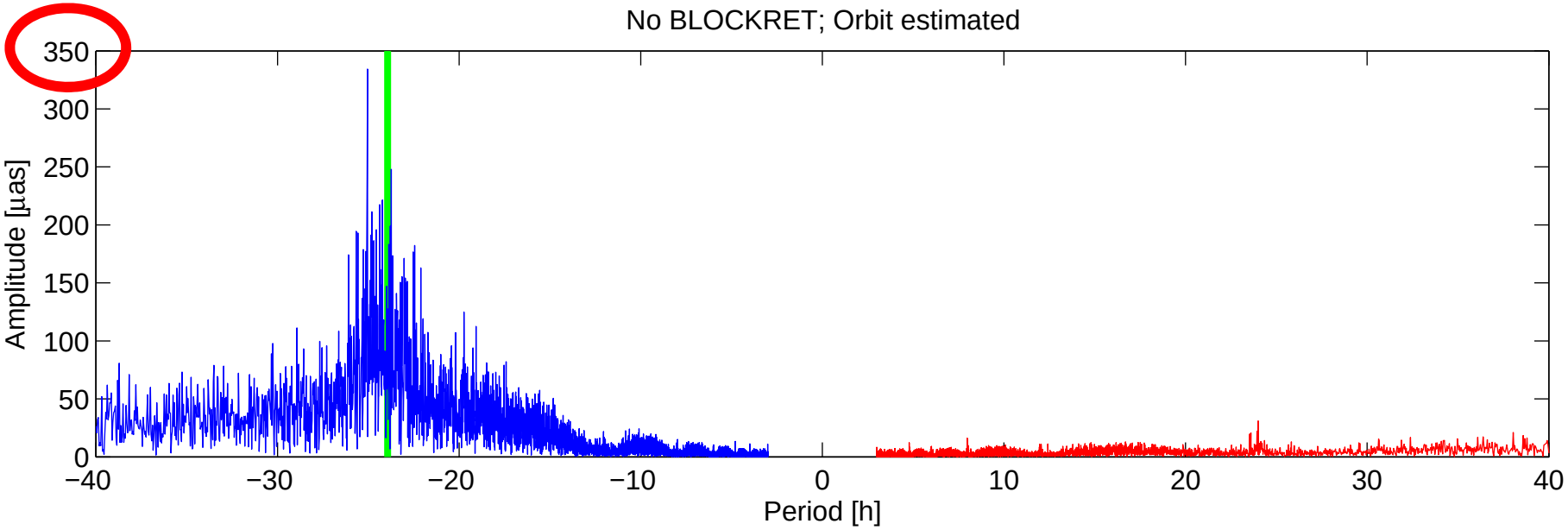
- Transformation inertial – terrestrial with **orbits**:

$$\mathbf{r}(t) = a \cdot \mathbf{R}_3(-\Omega) \cdot \mathbf{R}_1(-i) \cdot \mathbf{R}_3(-u) \cdot \mathbf{e}_1$$

$$\mathbf{r}'(t) = a \cdot \mathbf{R}_3(-\Omega - \delta\Omega) \cdot \mathbf{R}_1(-i - \delta i) \cdot \mathbf{R}_3(-u - \delta u) \cdot \mathbf{e}_1$$

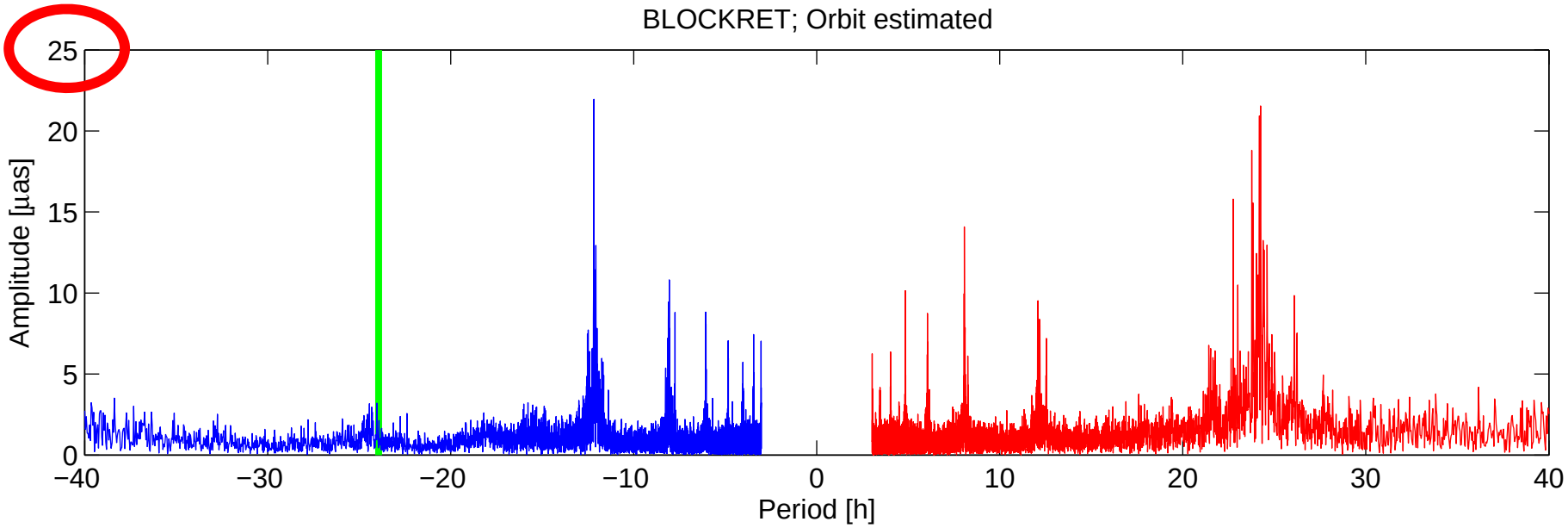
$$= \mathbf{R}_3(\zeta) \cdot \mathbf{R}_2(\xi) \cdot \mathbf{R}_1(\eta) \cdot \mathbf{r}(t)$$

Retrograde-diurnal PM and orbits



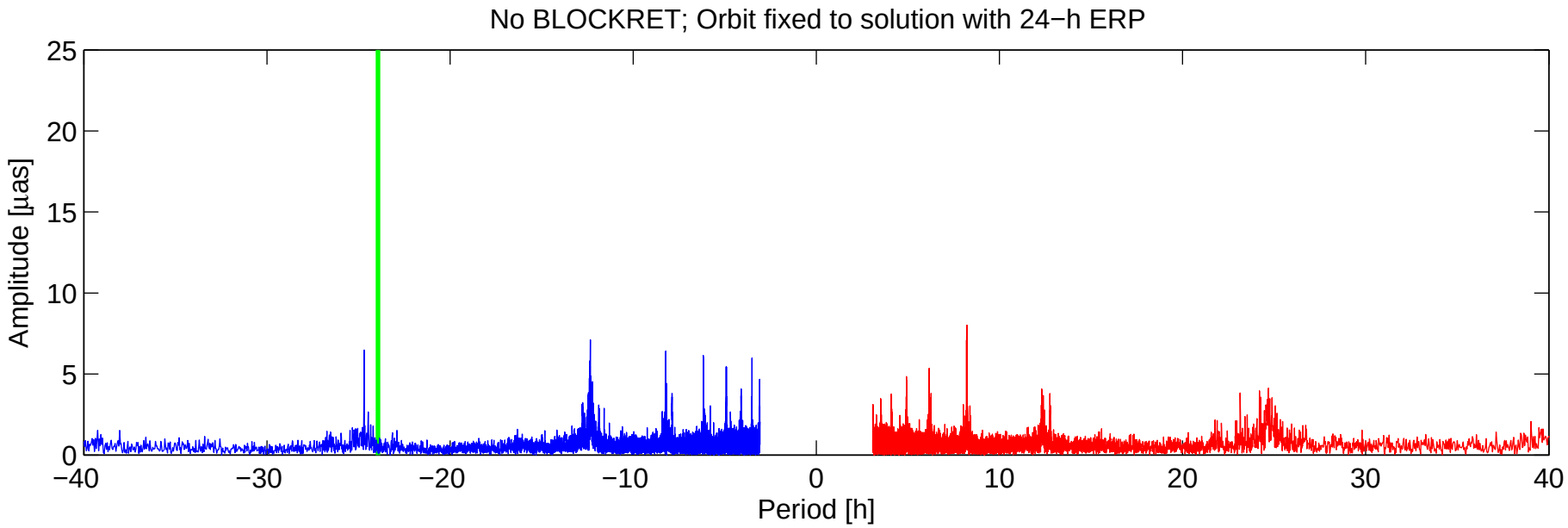
- Correlation with orbits produces big peaks in spectra around retrograde-diurnal period

Retrograde-diurnal PM: BLOCKRET constraint



- Blocking / constraining the retrograde-diurnal signal removes the correlation with the orbits

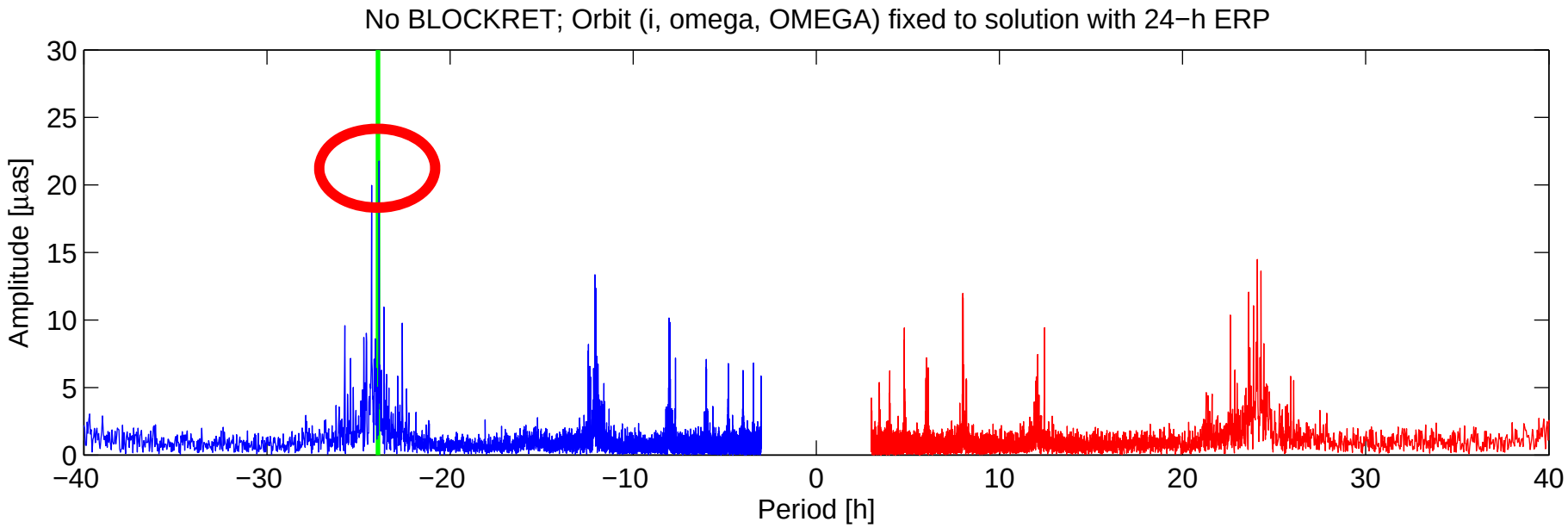
Retrograde-diurnal PM: Orbit parameter fixed



Fix all orbital elements+empirical+stochastic parameters:

- No retrograde-diurnal polar motion ✓
- Other frequencies blocked as well ? ??

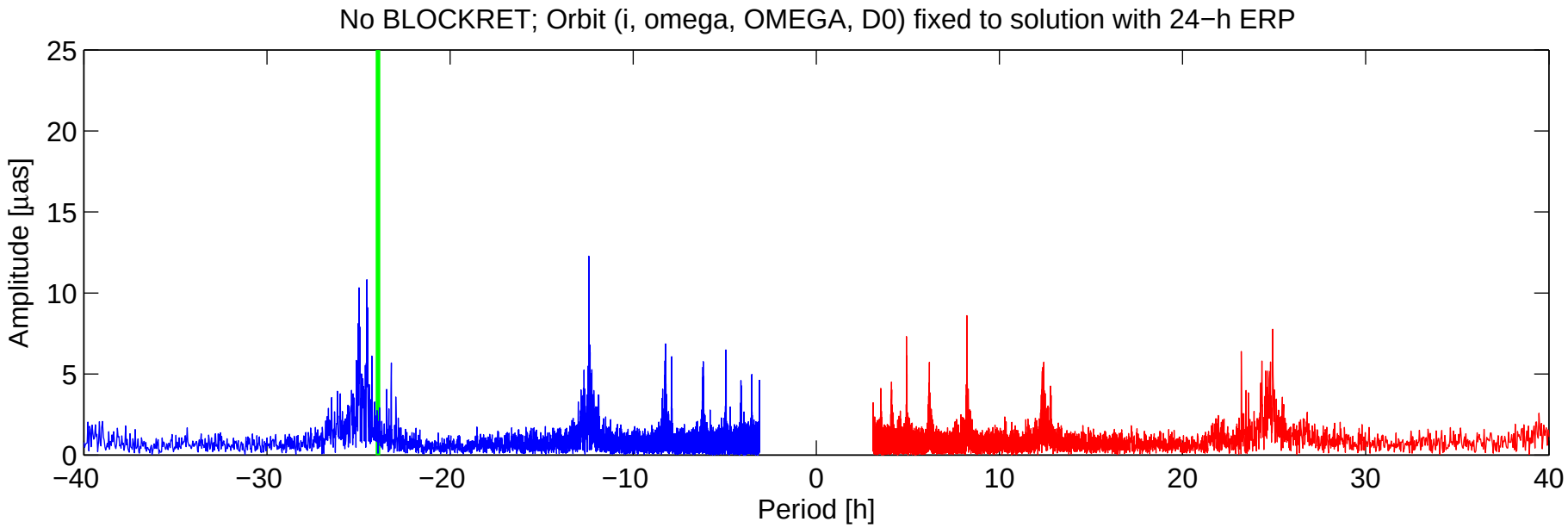
Retrograde-diurnal PM: Correlated params fix



Fix only i, ω, Ω (from theoretical considerations):

- Small retrograde-diurnal polar motion remains ??
- Other frequencies seem to be okay ✓

Retrograde-diurnal PM: Correlated params fix



Due to orbit perturbation: D0 (direct solar radiation pressure) is additionally involved in correlation

$\Rightarrow$ Fix only i, ω, Ω + D0:

- No retrograde-diurnal polar motion ✓
- Other frequencies seem to be okay ✓

GNSS-only solutions: Summary

- Scatter in time-series of sub-daily polar motion (PM) is at the level of 150 - 170 μas
- Constraint for blocking retrograde-diurnal PM works fine, but **neighbour frequencies** are affected as well
- Not only the orbital elements (i, ω, Ω) are **correlated with a retrograde-diurnal** signal in PM
- **Empirical orbit parameters** are involved as well
- Introducing (and fixing) the **orbit from a solution with 24-h ERPs** gives promising results (but might remove «real» signals)

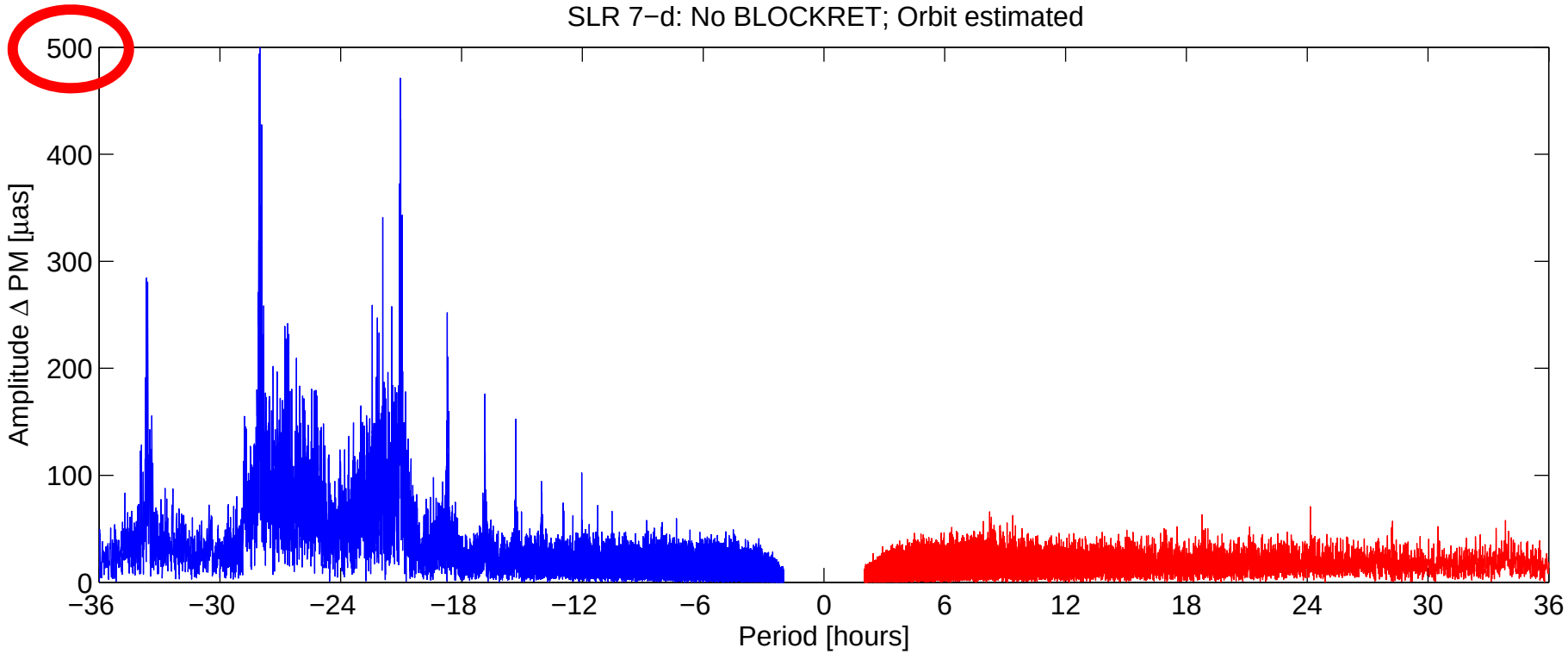
SLR solutions

LAGEOS + ETALON satellites are taken into account.

Observation statistics for 2001 – 2011:

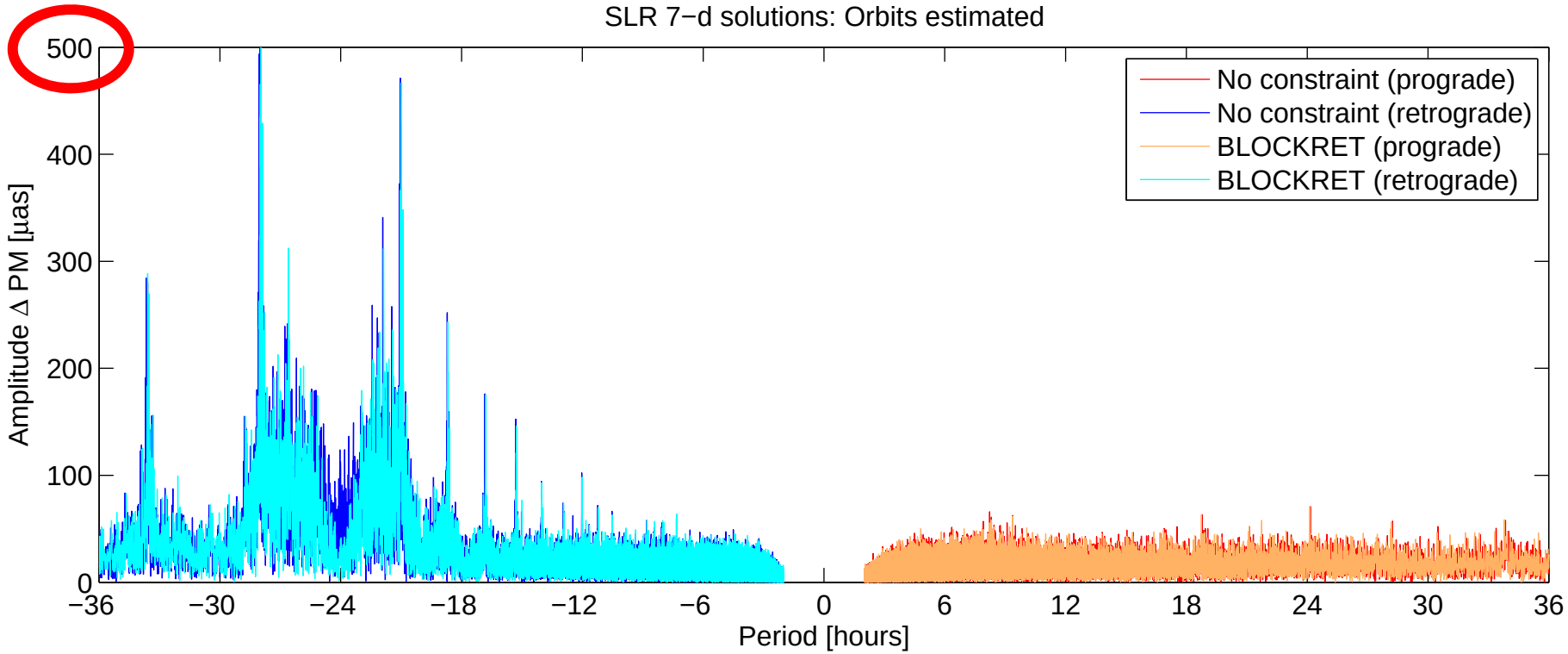
- About 3000 observations per week
- 1-h resolution for ERPs = 168 intervals per week
- Empty 1-h intervals: 622 out of 96'264 (=0.6%)

SLR solutions



- Full correlation between orbits and polar motion evokes signals up to 500 μas in retrograde spectra

SLR solutions

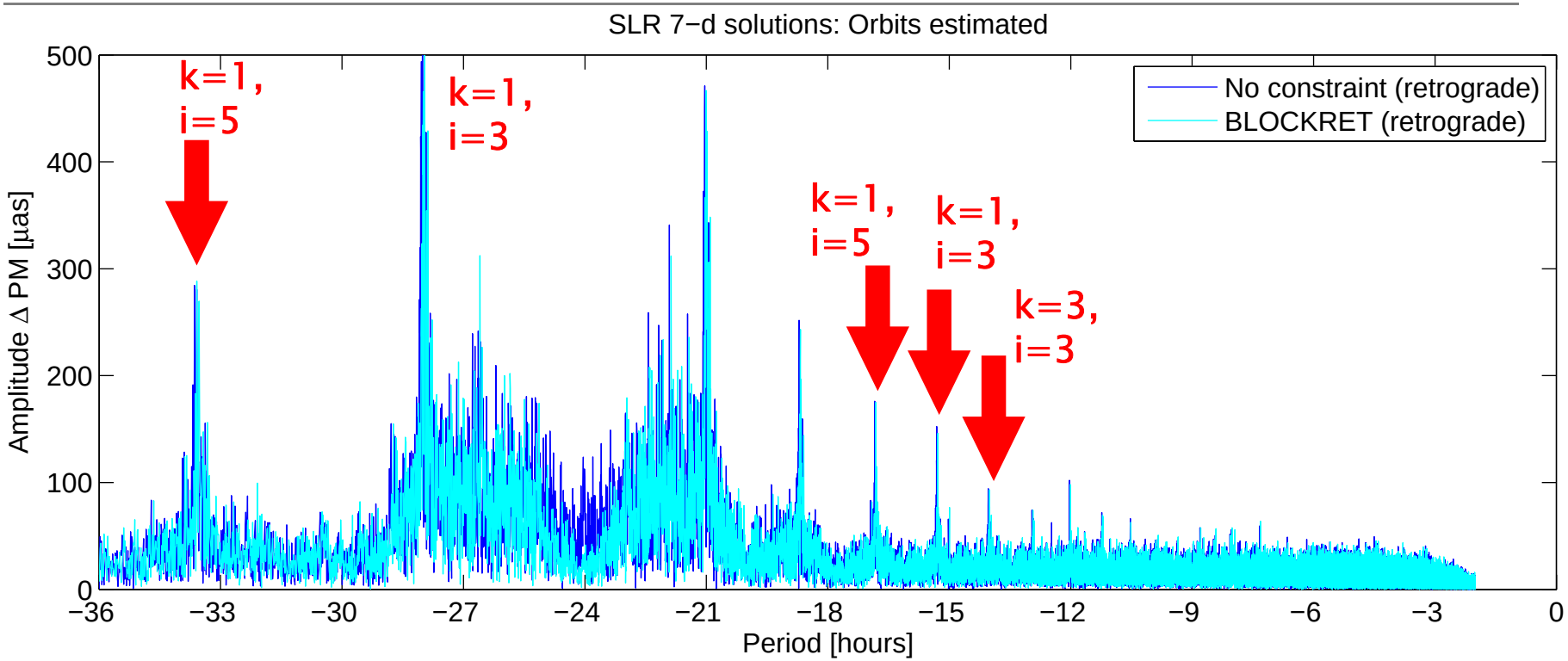


- BLOCKRET removes retrograde-diurnal signal

But:

- Several (artefactual) signals remain

SLR solutions

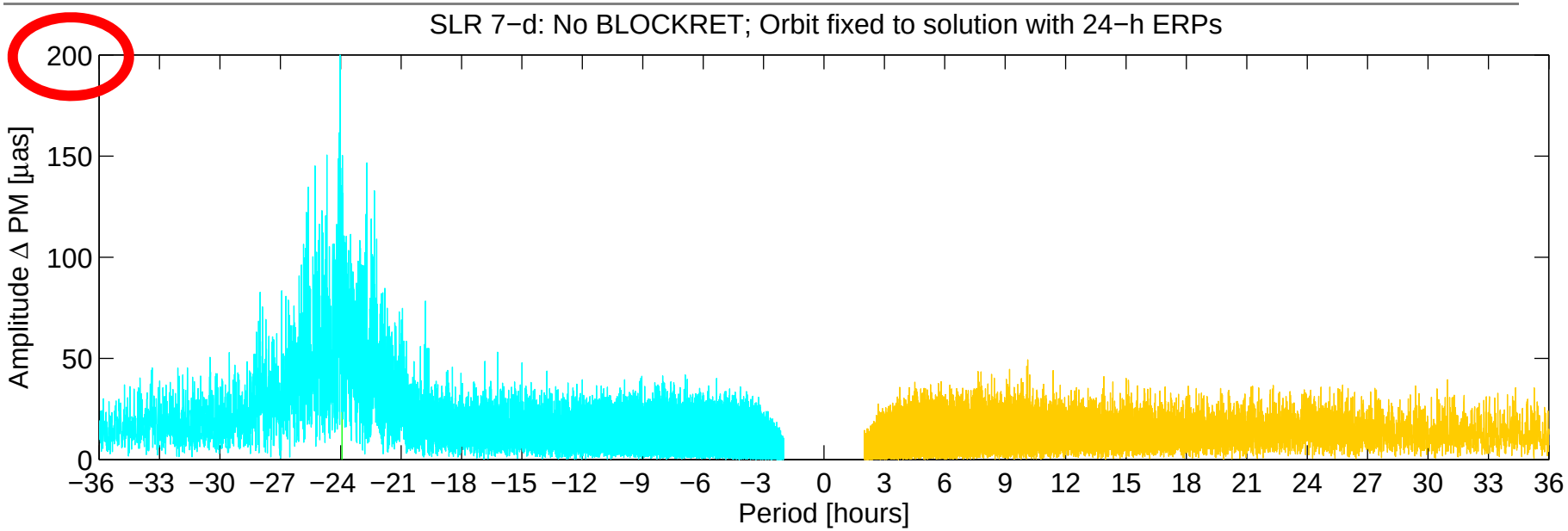


Combinations of the LAGEOS revolution period ($n_L = 2\pi / \mathbf{3.75h}$)

and the revolution period of the Earth ($n_E = 2\pi / \mathbf{23.93\ h}$):

$$\frac{2\ \pi}{k \cdot n_L \pm i \cdot n_E}$$

SLR solutions

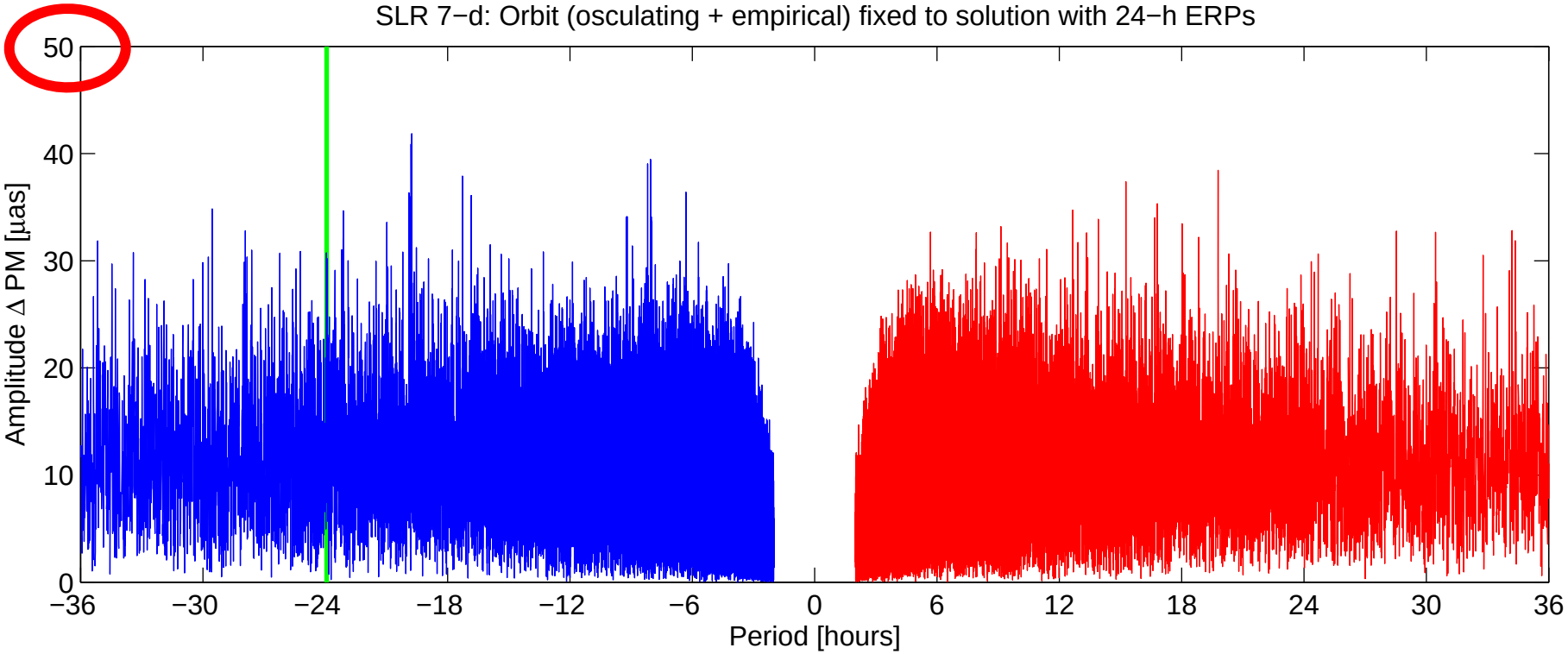


- Fixing orbital elements (osculating elements only) reduces the noise level

But:

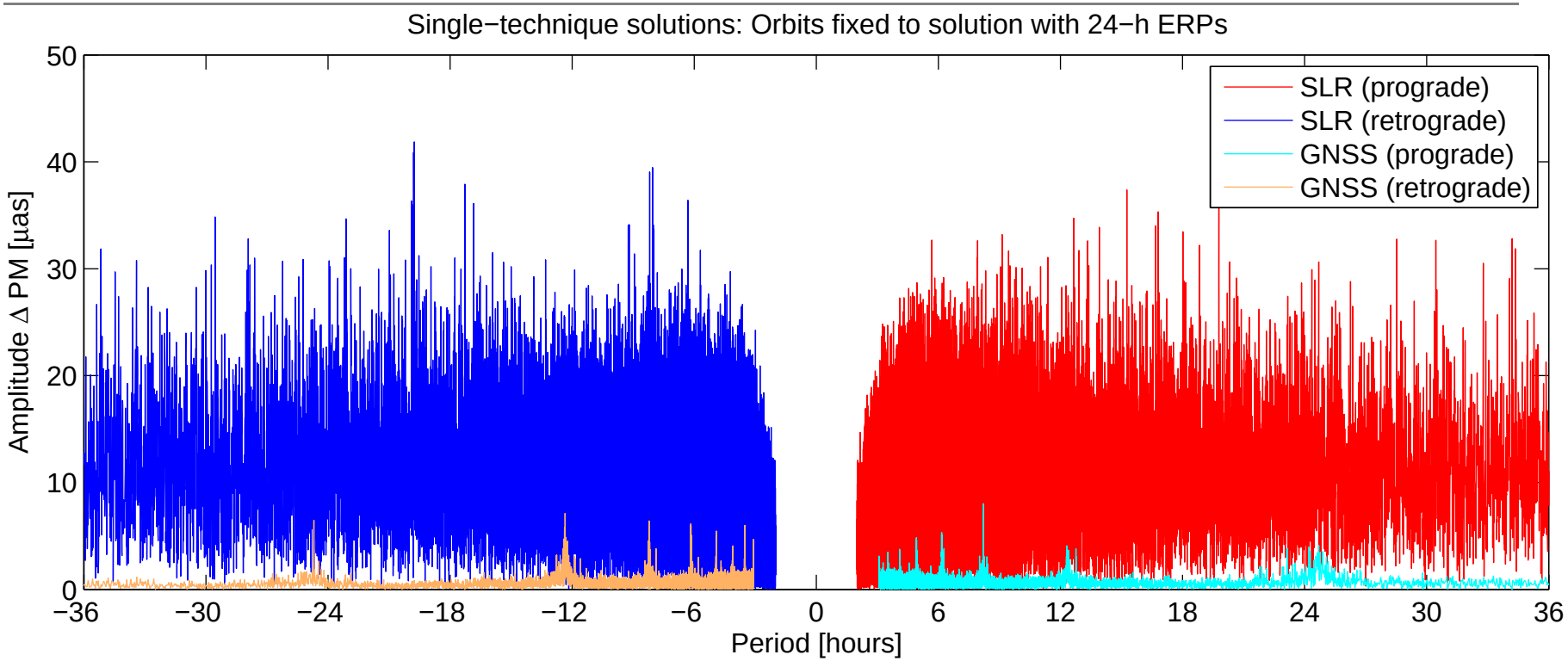
- «Signals» around 24 h remain -> artefacts

SLR solutions



- Fixing orbits (osculating elements and empirical parameters) further reduces the noise level
- No artefactual signals left
- But: «Real» signals are hardly detectable

SLR vs. GNSS solutions



The noise level in the SLR series is 6–10 times larger than in the GNSS series.

Combined GNSS-SLR solutions

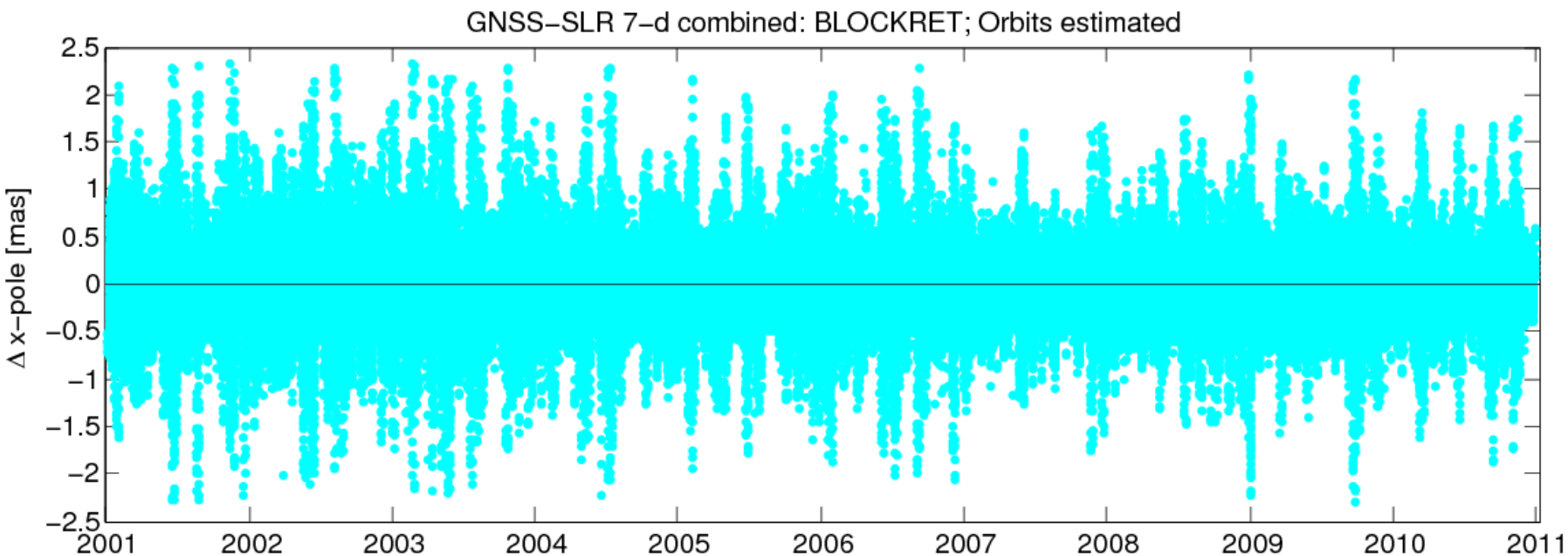
- Microwave data: GPS / GLONASS
- SLR data: GPS / GLONASS
- SLR data: LAGEOS / ETALON

→ Common orbit parameters

Complication for estimation of sub-daily ERPs due to **different arc-lengths**:

- GNSS satellites: **3 days** (overlapping)
- LAGEOS, ETALON: **7 days** (no overlaps)

Combined GNSS-SLR solutions



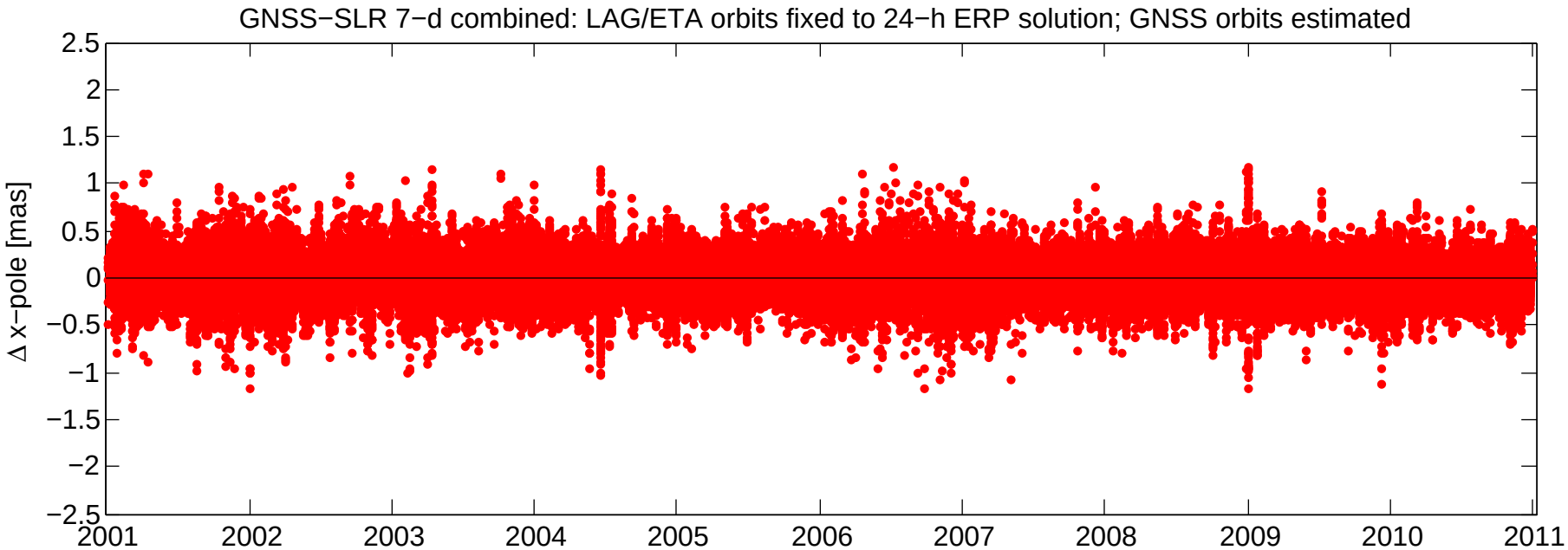
<- BLOCKRET for 7 days

Weekly combined solutions:

- 7-day arc LAGEOS/ETALON
- 3-day arc GNSS satellites

=> «LAGEOS» artefacts and small correlations w.r.t. 3-day GNSS arcs remain

Combined GNSS-SLR solutions



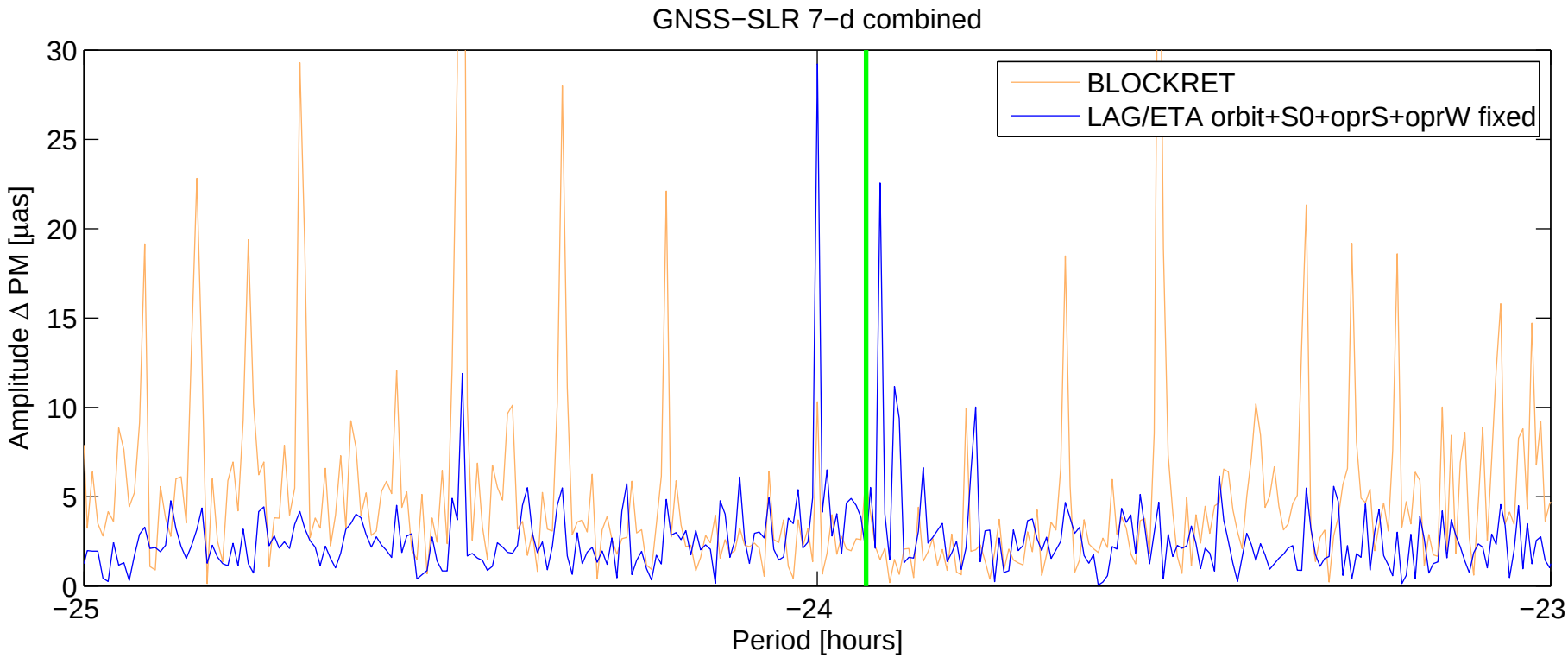
Weekly combined solutions:

- 7-day arc LAGEOS/ETALON
- 3-day arc GNSS satellites

<- fixed to 24-h ERP solution

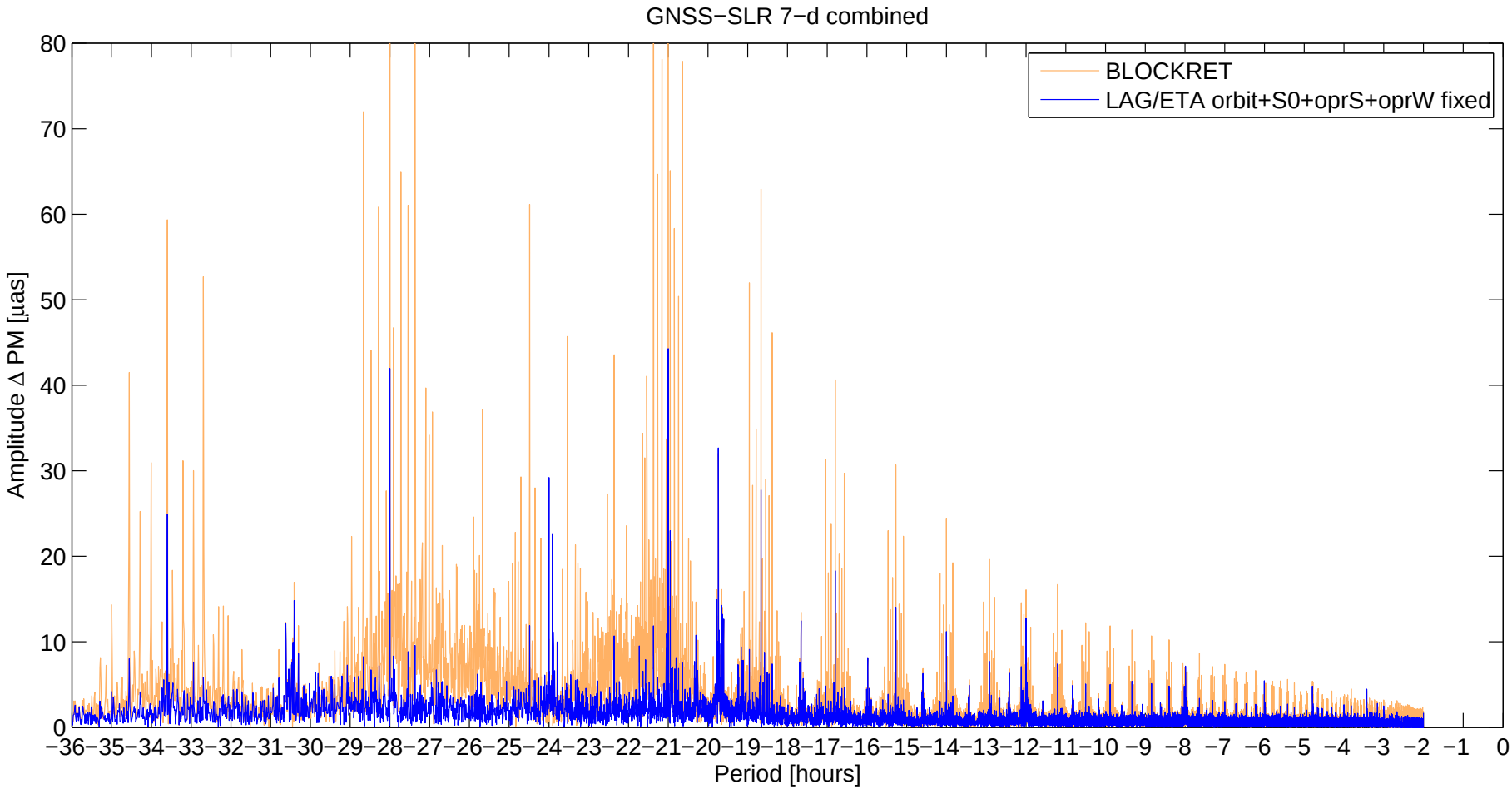
=> No remaining correlations ?

Combined GNSS–SLR solutions



- Fixing the orbits of the LAGEOS/ETALON satellites (osculating elements + empirical orbit parameters) fully removes the correlation
- GNSS orbits do not need to be fixed additionally

Combined GNSS-SLR solutions



Many artefactual periods are still present

-> less pronounced if orbits are fixed

Conclusions

- Orbits with different characteristics evoke different artefacts in subdaily polar motion (PM) series
- GNSS (revolution period $\approx$ 0.5 * diurnal):
  - Blocking the retrograde-diurnal PM is enough
  - Alternatively: Fixing the orbit of a 24-h ERP solution (orbital elements AND empirical parameters!)
- SLR-LAGEOS (revolution period $\ll$ diurnal):
  - Blocking the retrograde-diurnal PM is not sufficient
  - Fixing the orbit of a 24-h ERP solution is the preferred method
- Combined GNSS-SLR solutions:
  - All orbital characteristics show up in PM series
  - Fixing one type of orbit is enough