Improved GNSS-Based Precise Orbit Determination by using highly accurate clocks

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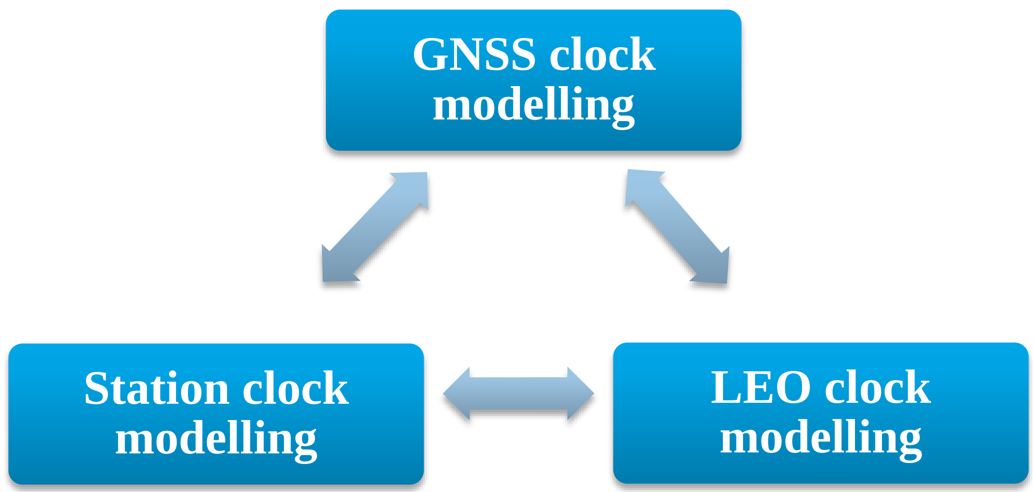
Outline

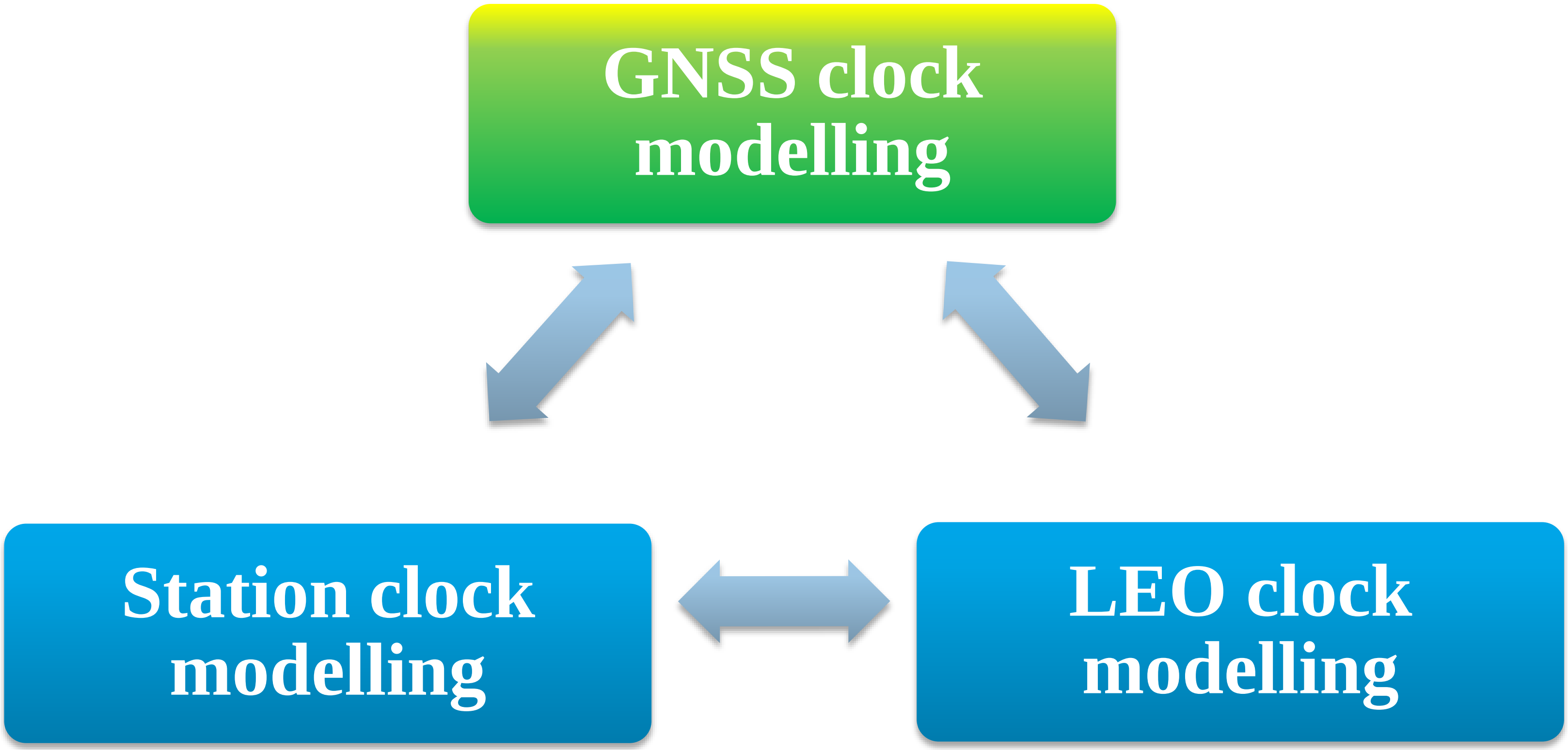
- Project overview
- Clock modelling for GNSS POD
- Kinematic orbit determination for GNSS with satellite clock modelling
- Clock modelling for kinematic LEO POD
- Sentinel 3-A clock assessment

Project Overview

- To investigate potential of modern satellite clocks for physical clock modelling for improving Precise Orbit Determination (POD) for GNSS and Low Earth Orbiting (LEO) satellites.
- Concepts and algorithms for clock modelling have been developed and their impact on POD for GNSS and LEO analyzed.



Clock modelling for GNSS POD



Clock modelling for GNSS POD

- Constraining of epoch-wise clock corrections to a clock model for highly accurate Galileo satellite clocks (Passive Hydrogen Masers):

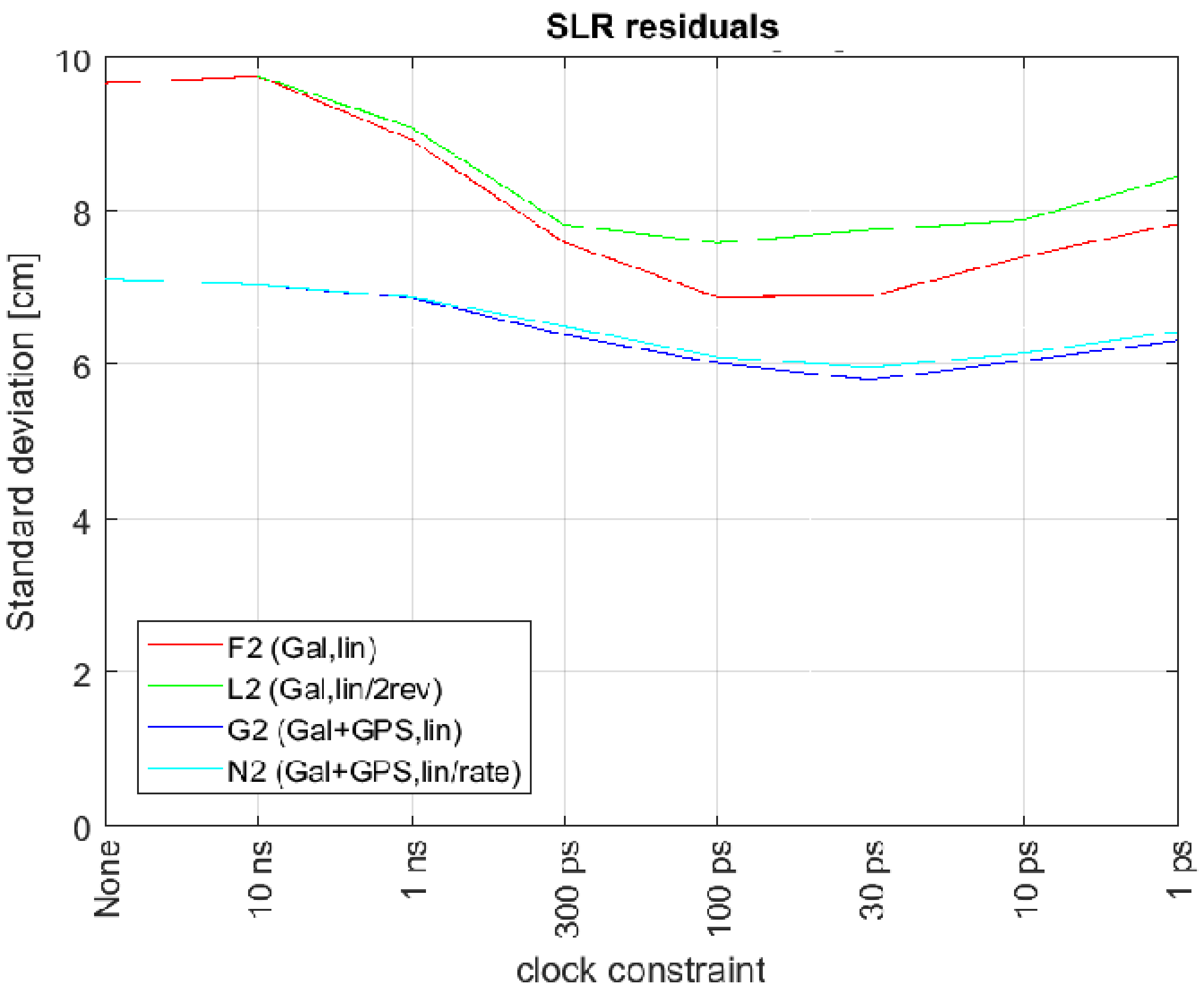
(1) „lin“: $\delta t(t) = a_0 + a_1(t - t_0)$

(2) „lin/rate“: $\delta t(t) = a_0 + a_1(t - t_0) + a_2(t - t_0)^2$

(3) „lin/2rev“: $\delta t(t) = a_0 + a_1(t - t_0) + c_2 \cos 2nt + s_2 \sin 2nt$

- Analysis of POD results for selected test scenarios.
- Time span of one week in 2016 (doy 059-065).

Clock modelling for GNSS POD



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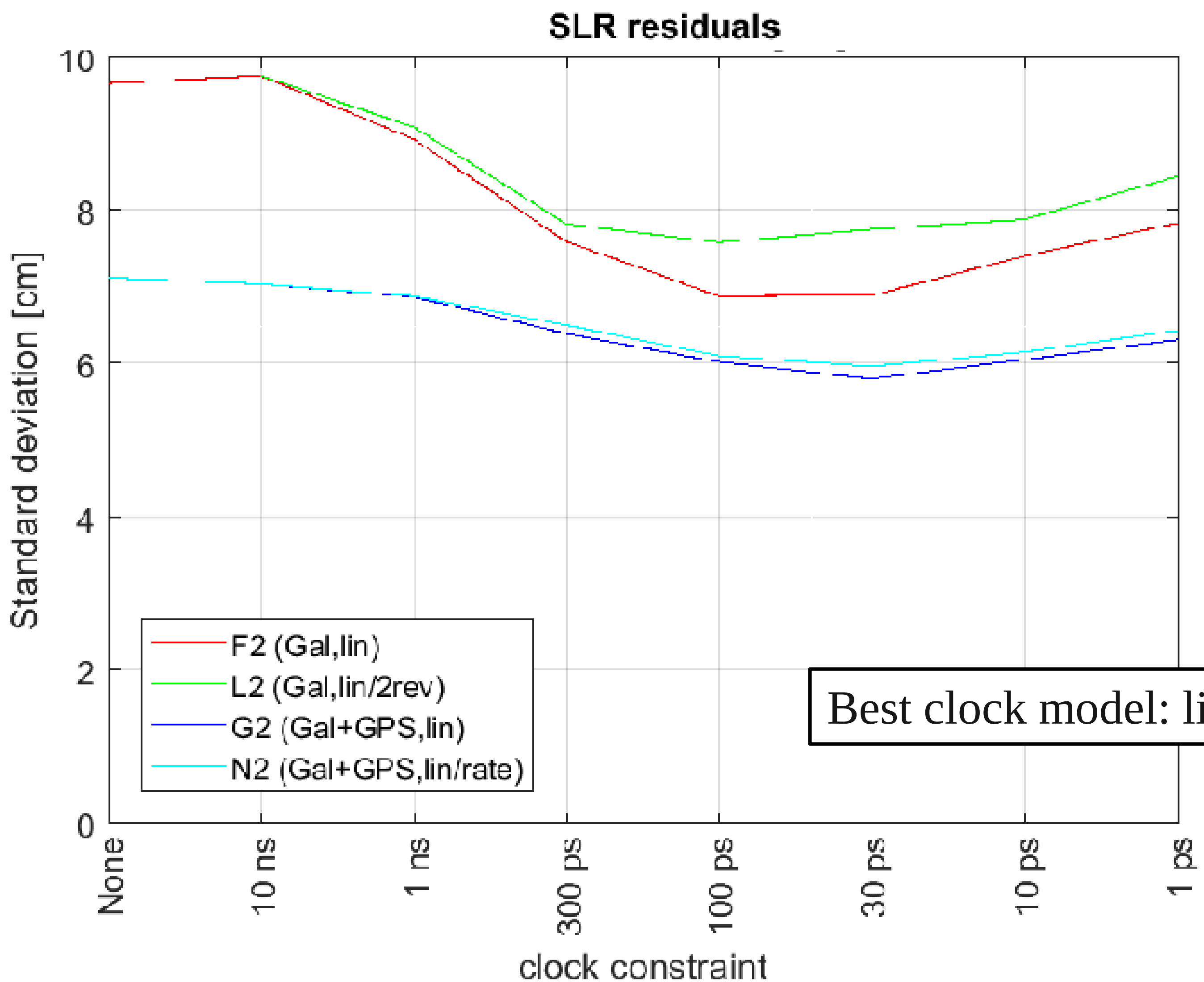
Clock modelling for GNSS POD



Best clock model: linear

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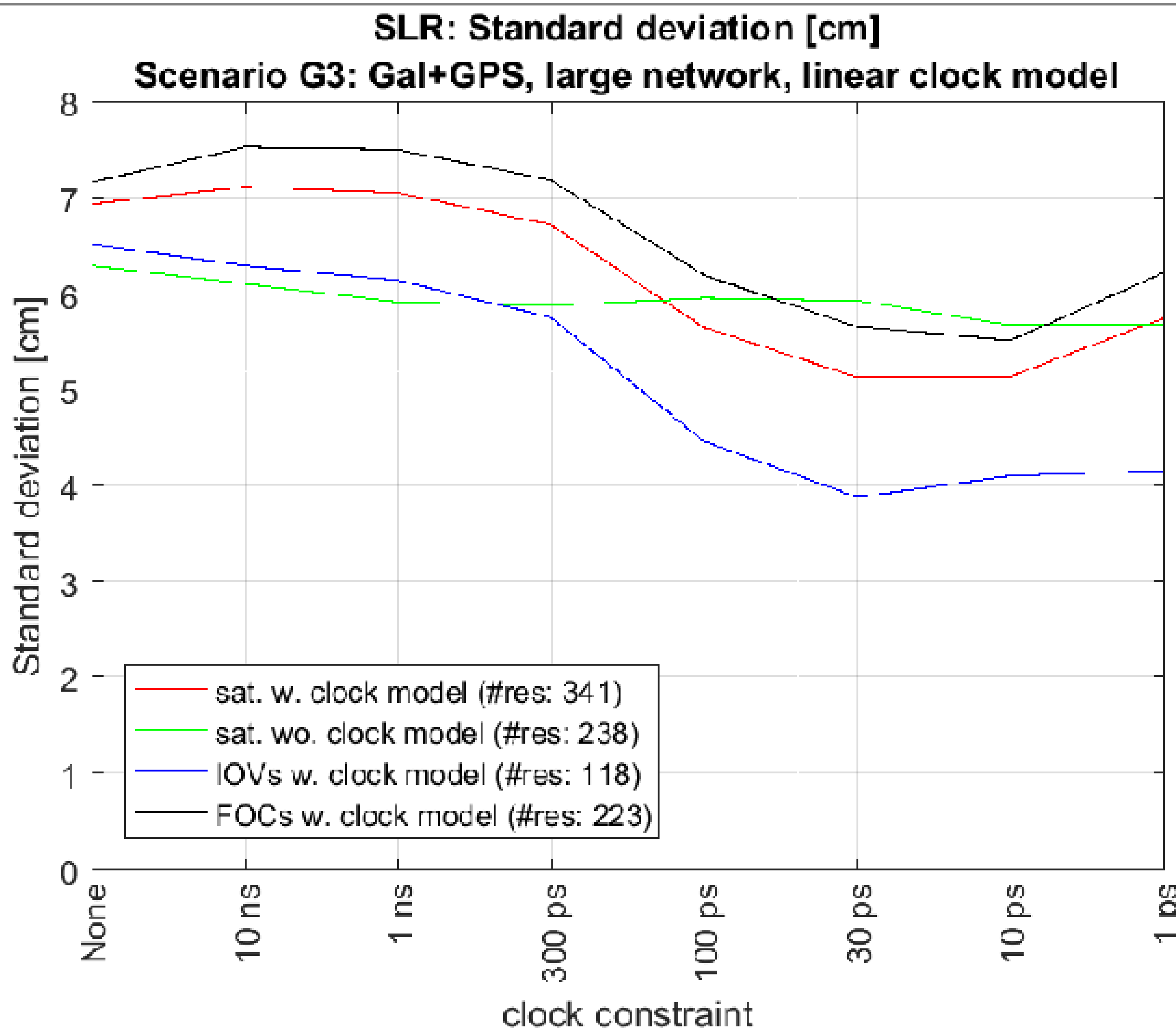
Clock modelling for GNSS POD



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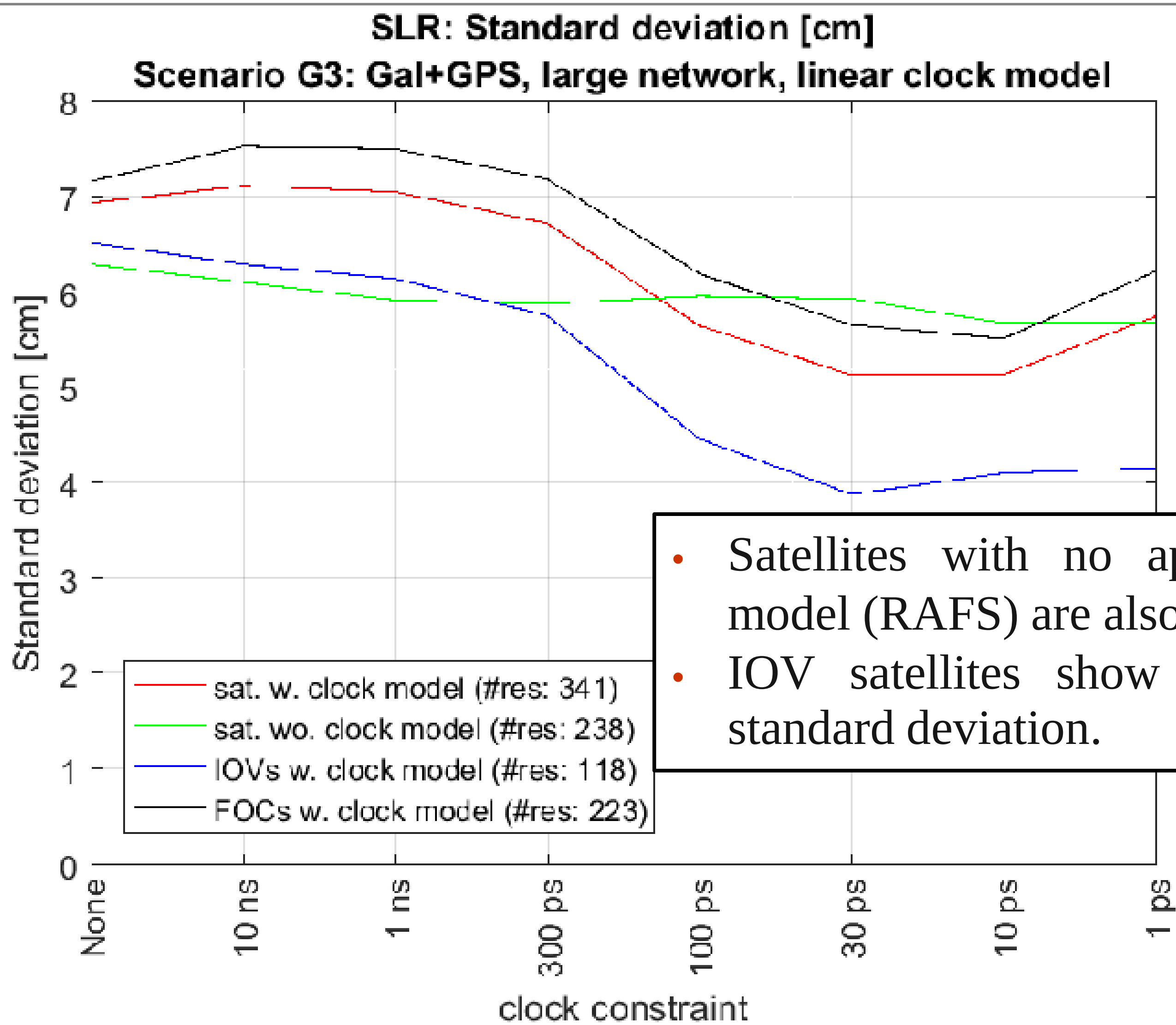
Clock modelling for GNSS POD



- Satellites with no applied clock model (RAFS) are also improved.
- IOV satellites show lower SLR standard deviation.

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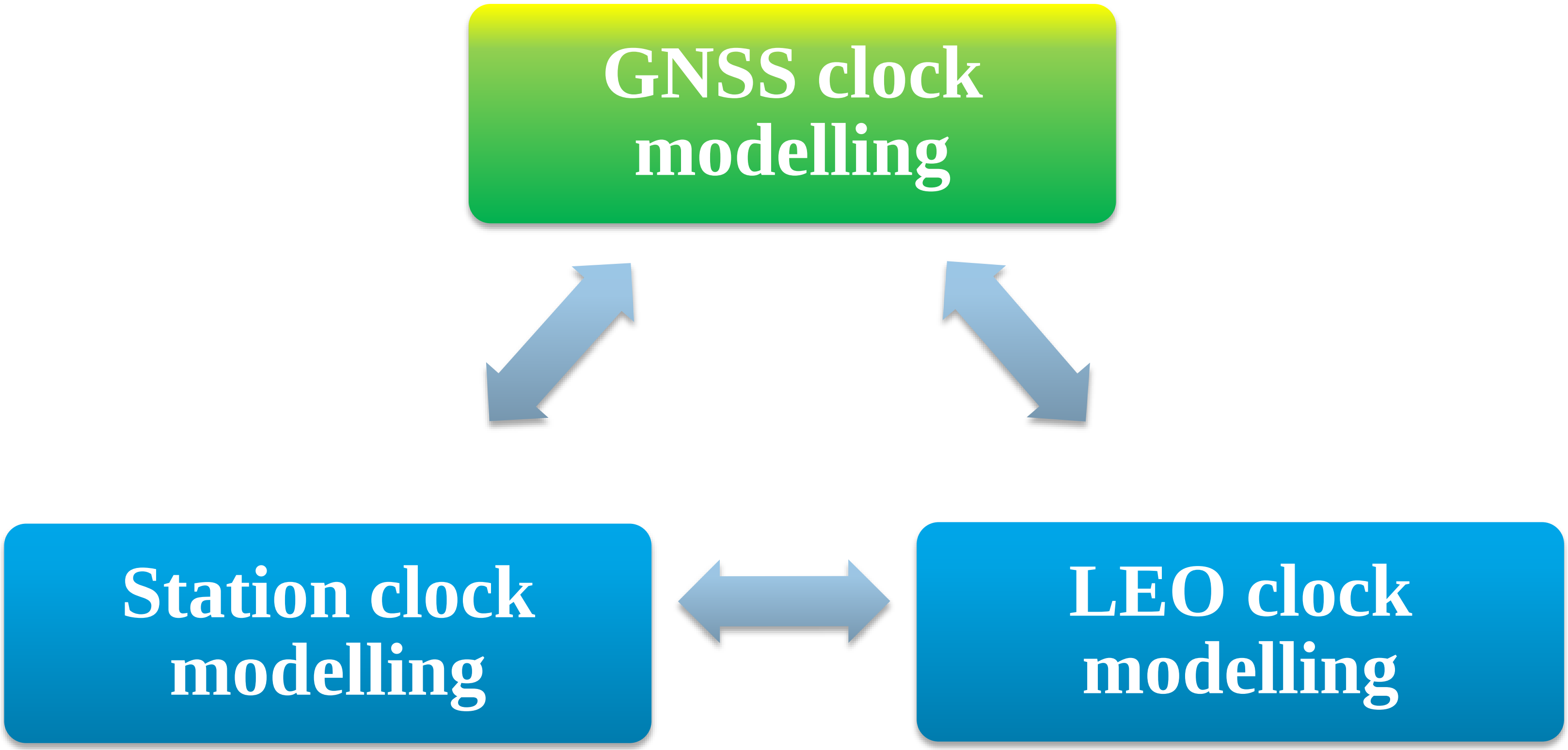
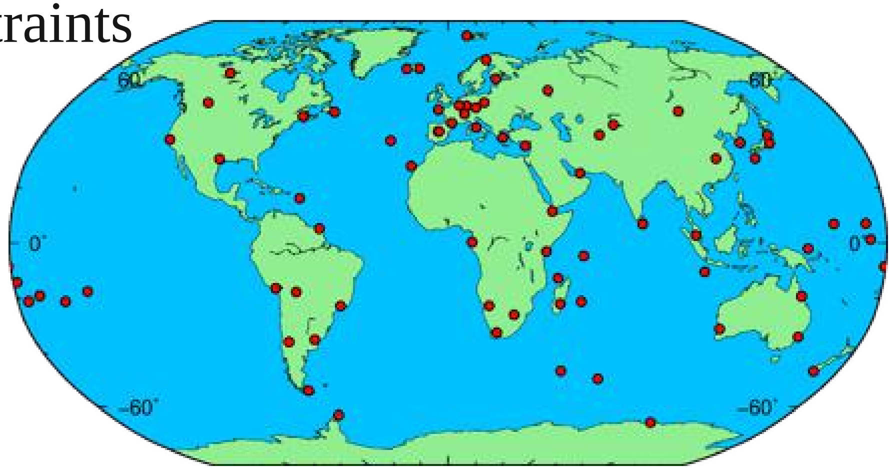
Kinematic orbit determination with satellite clock modelling



Kinematic orbit determination with satellite clock modelling

- **Goals:**
  - Determine optimum clock constraining for different clock types
  - Investigate dynamical orbit model deficiencies through clock modeling
- **Modelling the satellite clock with relative constraints:**
  - Deterministic 1st degree polynomial fit estimated
  - Stochastic epoch-to-epoch constraints
- **Satellites considered:**
  - Galileo: H-masers
  - GPS: Block IIF with RAFS



Data: 1 week, 5 min sampling, 74 stations

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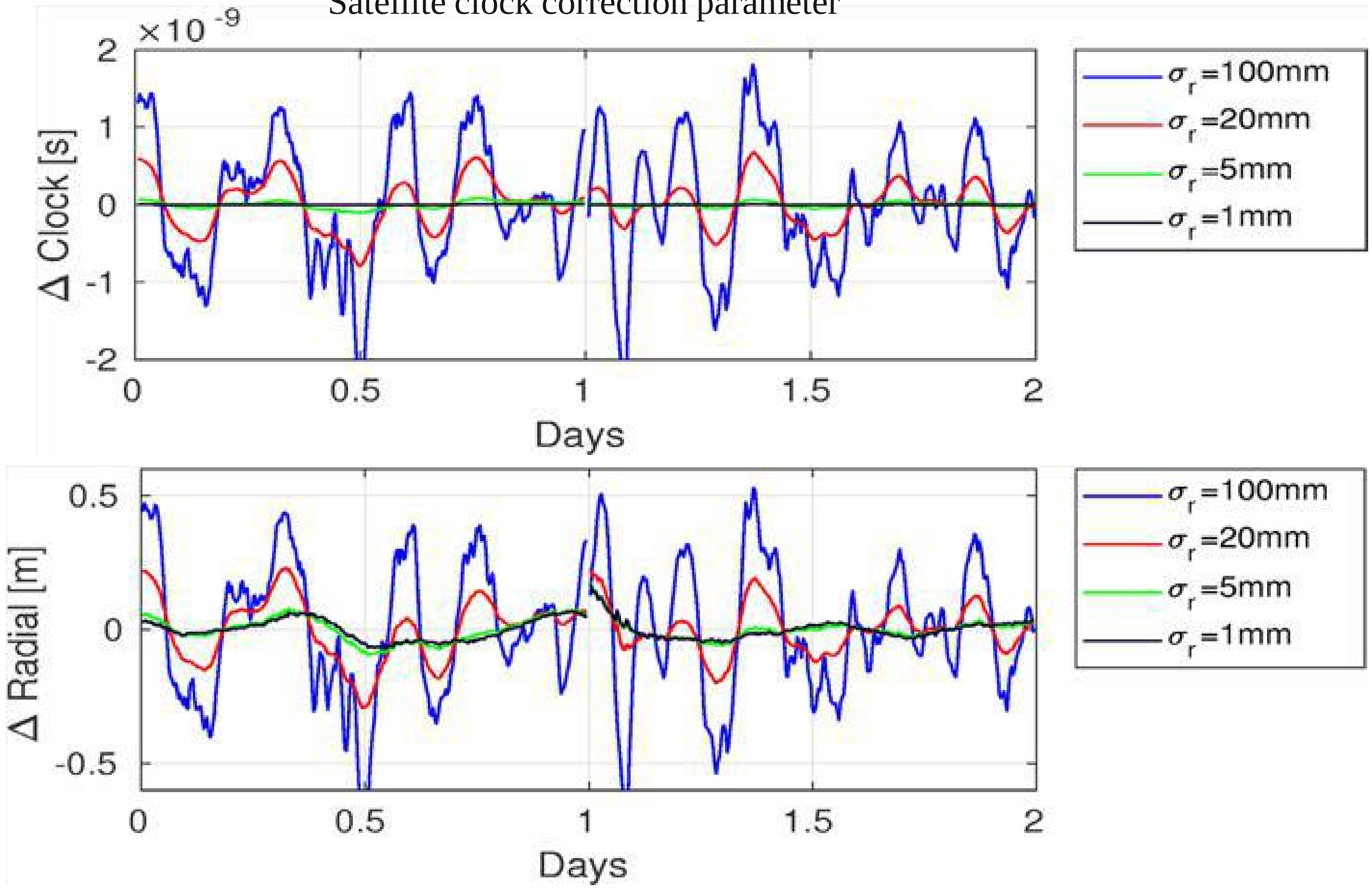
Effects of the clock constraints on the radial orbit component

- Compared with ESOC dynamic orbits; example for E19

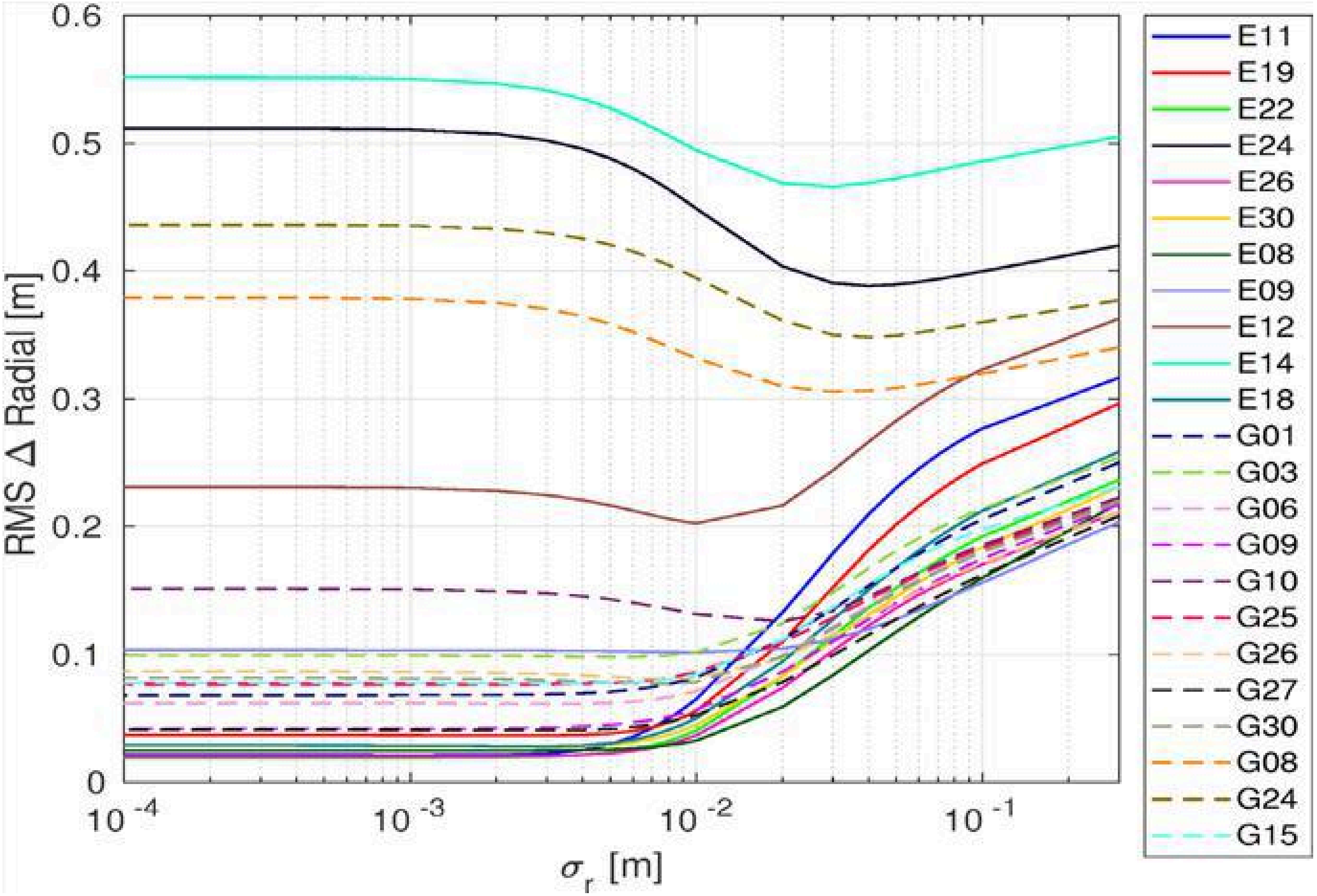
Satellite clock correction parameter



Difference of the radial component between the kinematic estimated orbits and the dynamic reference orbit.

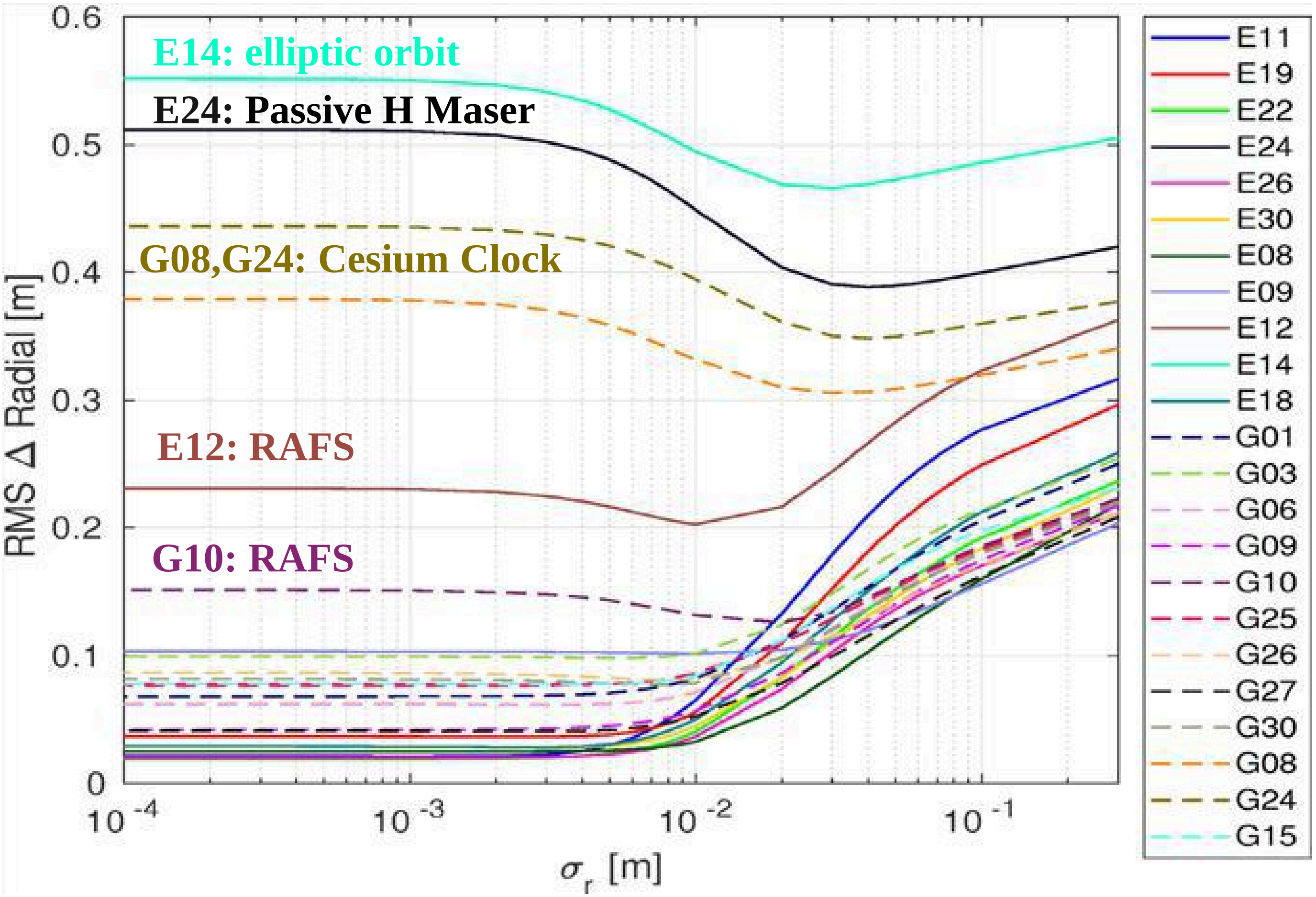
Effects of the clock constraints on the radial orbit component

- Compared with ESOC dynamic orbits;



Effects of the clock constraints on the radial orbit component

- Compared with ESOC dynamic orbits;



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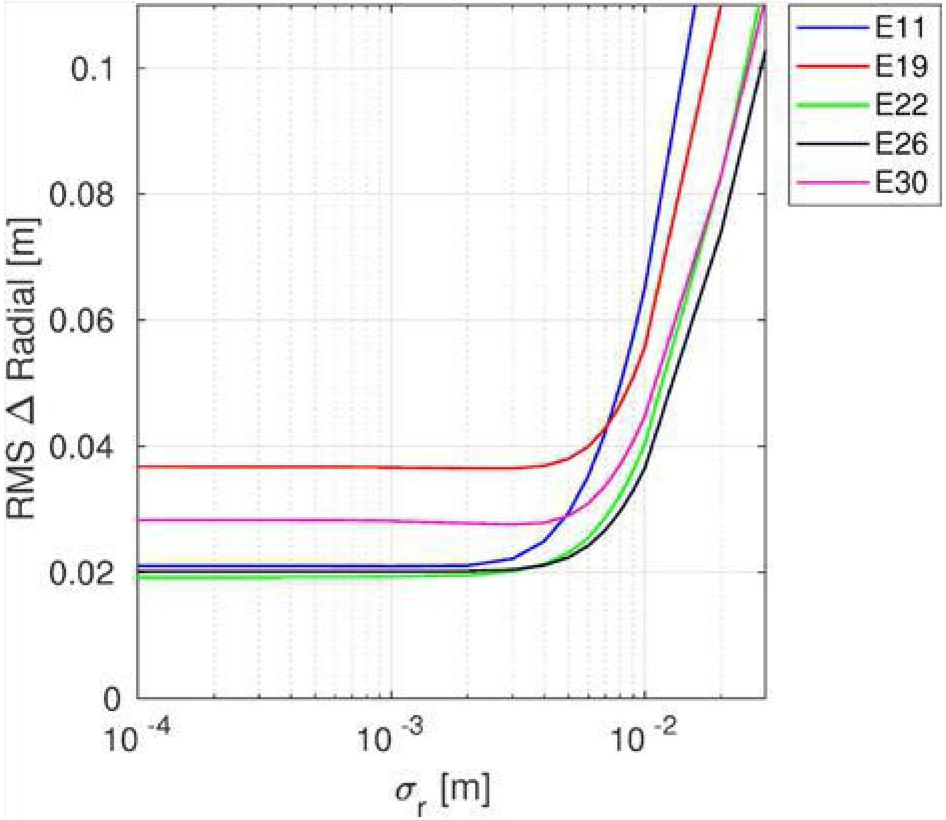
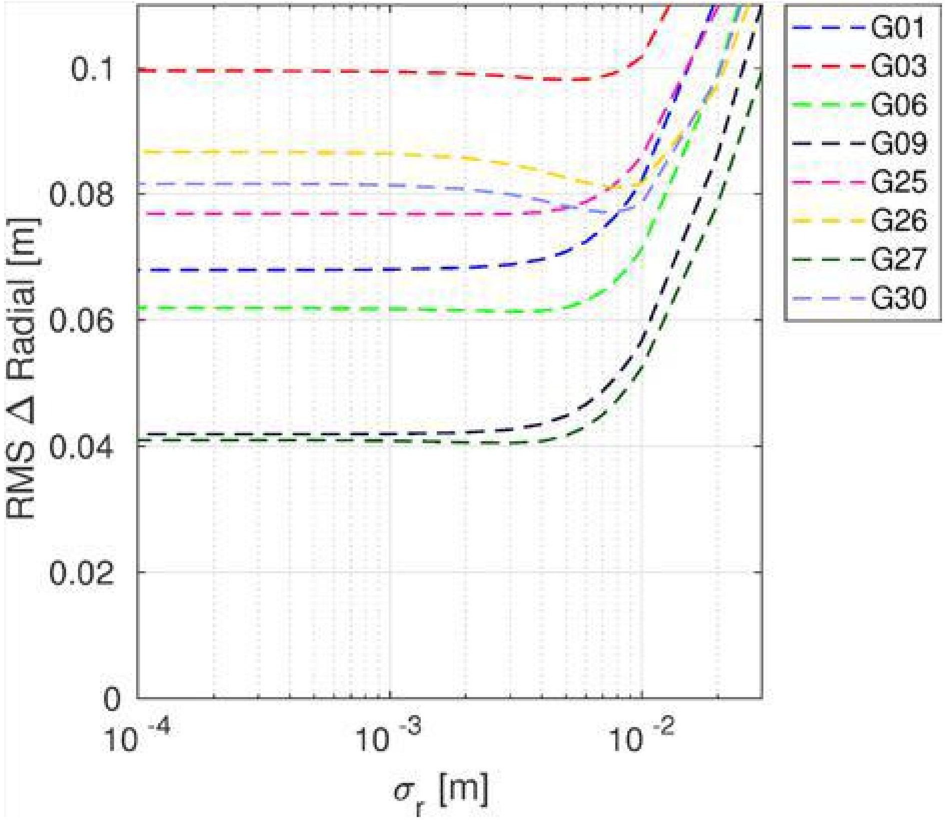
Effects of constraining the clock on the radial component

Galileo: mean RMS = 2.5 cm



Mean optimum σ_r = 1.6 mm

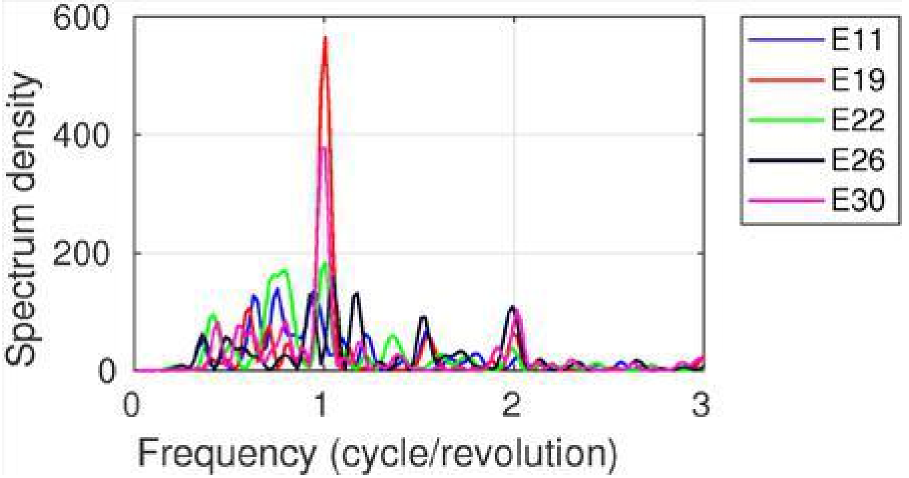
GPS: mean RMS = 6.8 cm

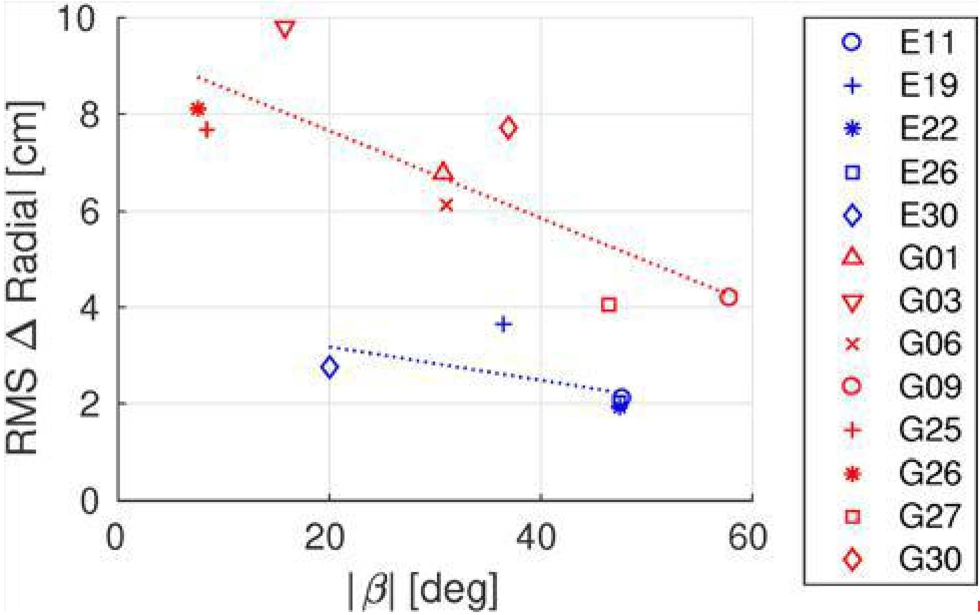


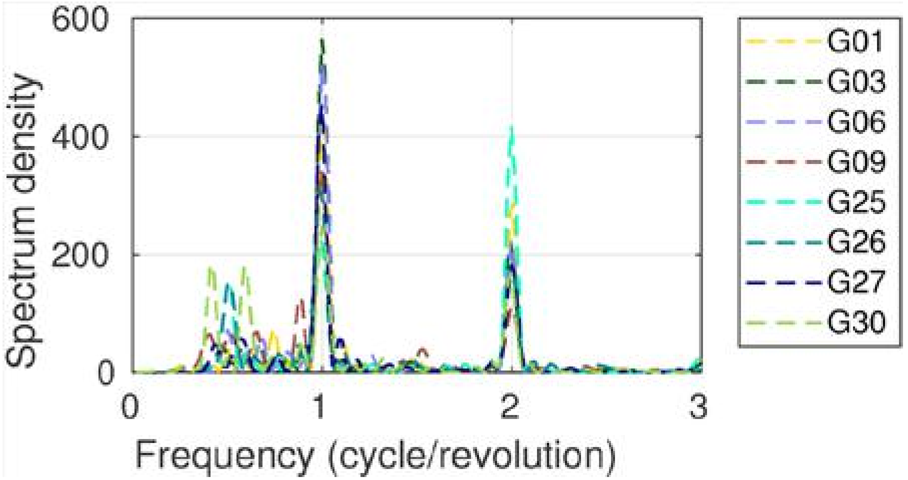
Mean optimum σ_r = 3.5 mm

What remains in the difference to the dynamic orbit and where does it come from ?

- Apparent β angle dependency indicates SRP model deficiencies.
- Strong 1/rev oscillation for Galileo satellites with lower β angles.
- Both 1/rev and 2/rev oscillations visible in GPS.







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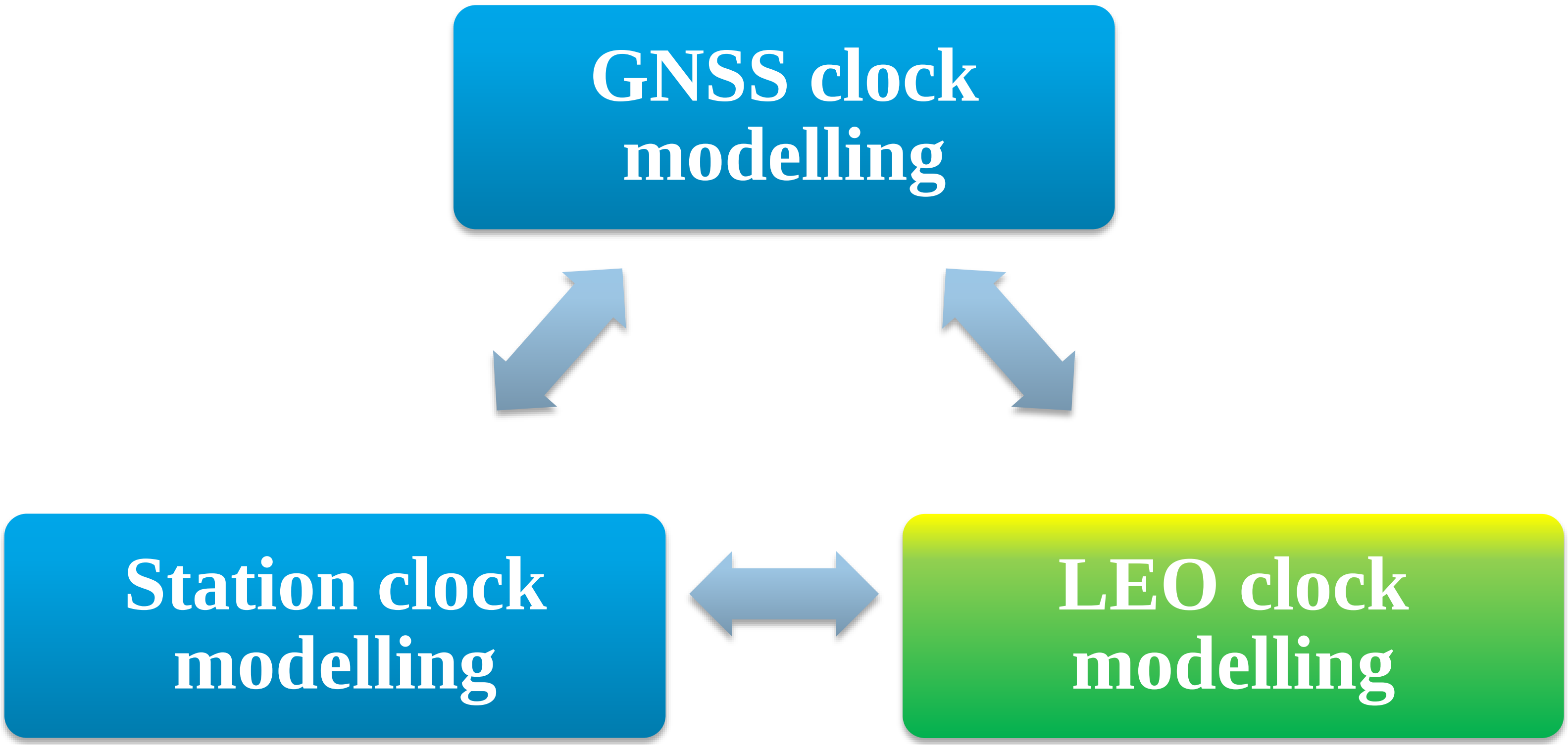
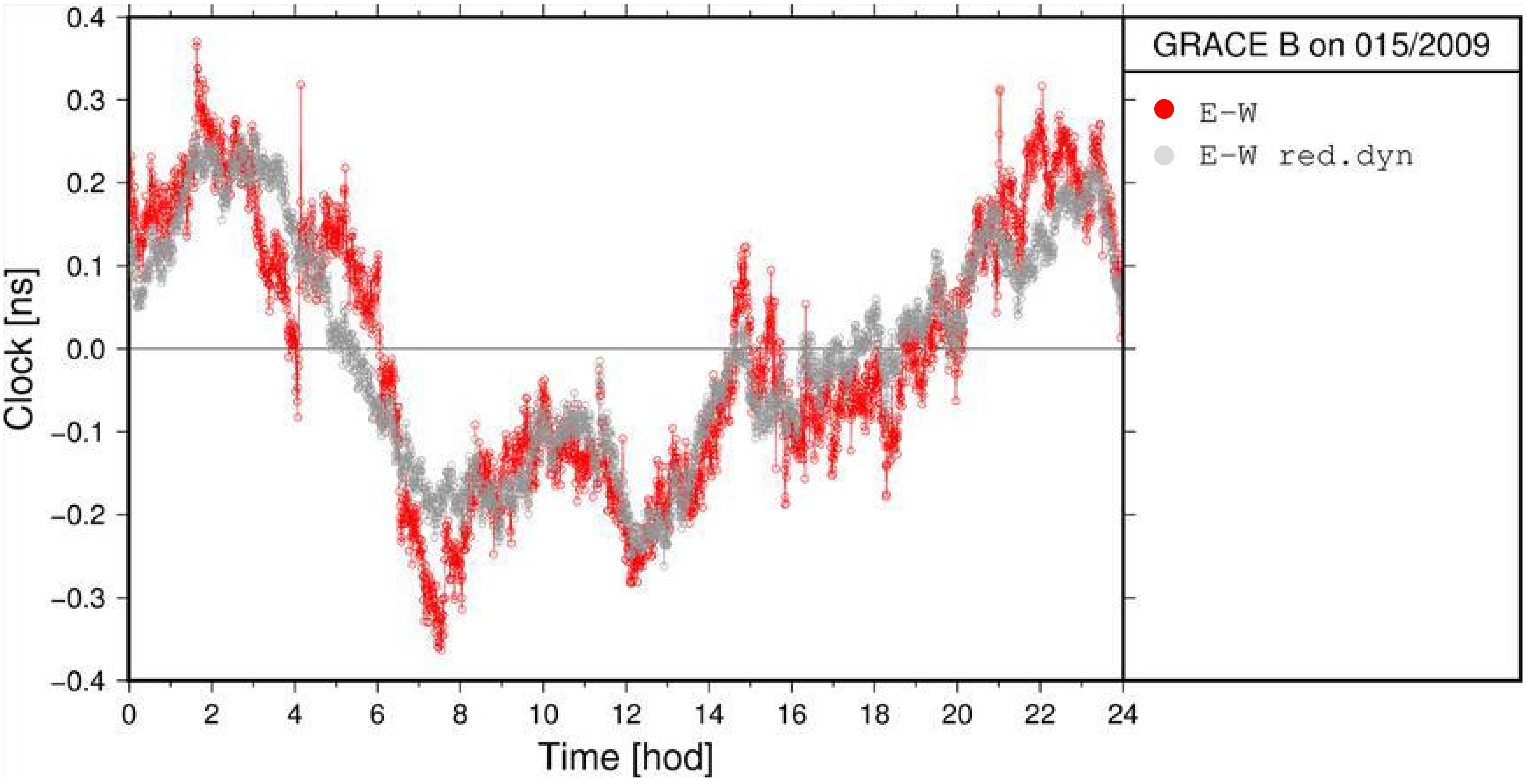
LEO clock modelling



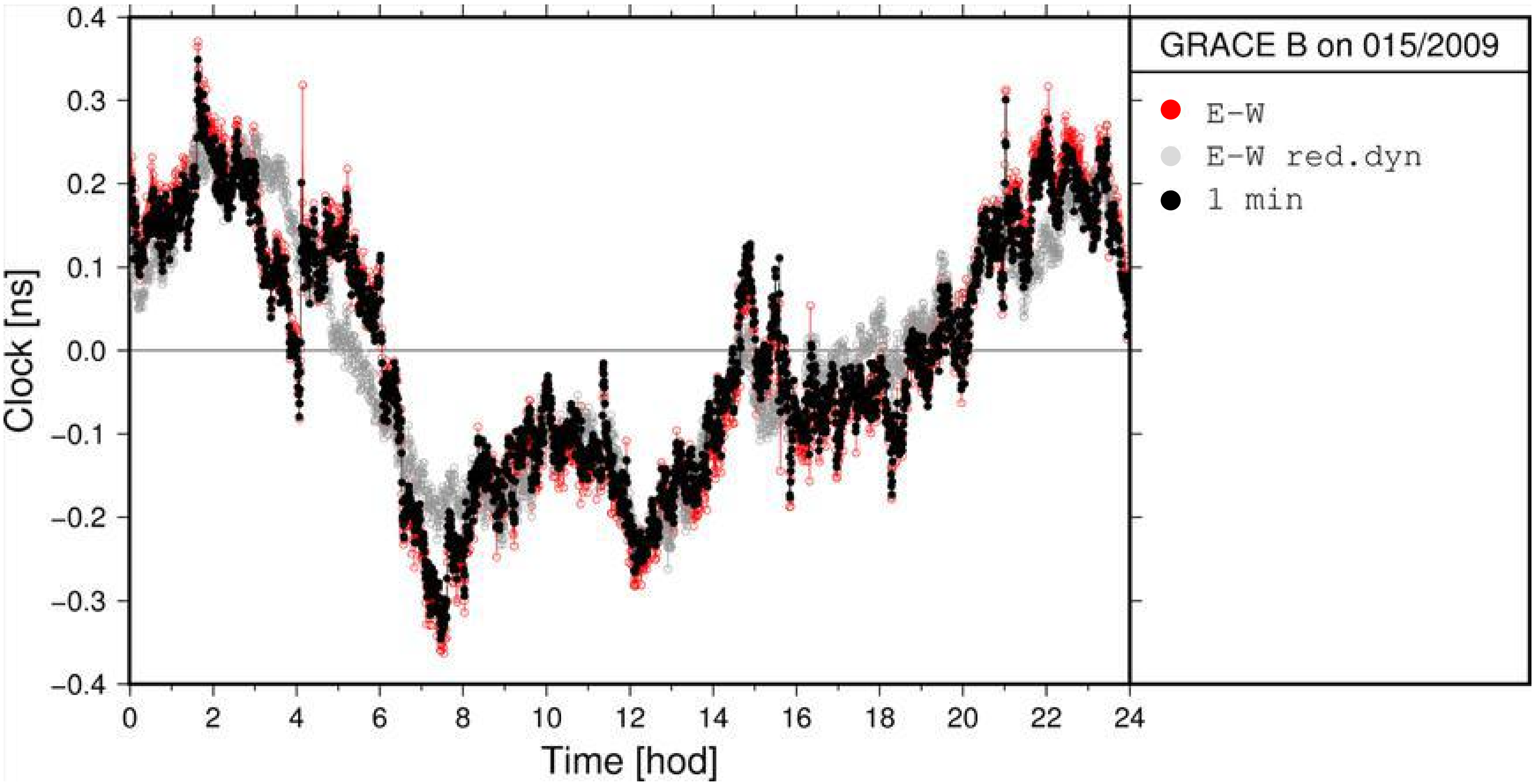
Clock modelling for kinematic LEO POD

- Deterministic clock modelling:
  → clock behavior is modelled as unconstrained piece-wise linear function with a certain number of knot points over 24 hours (1 min, 2 min, 3 min and 5 min).
- Applied on GRACE A and GRACE B POD, using data from January 2009.
- Sentinel 3-A receiver clock assessment.

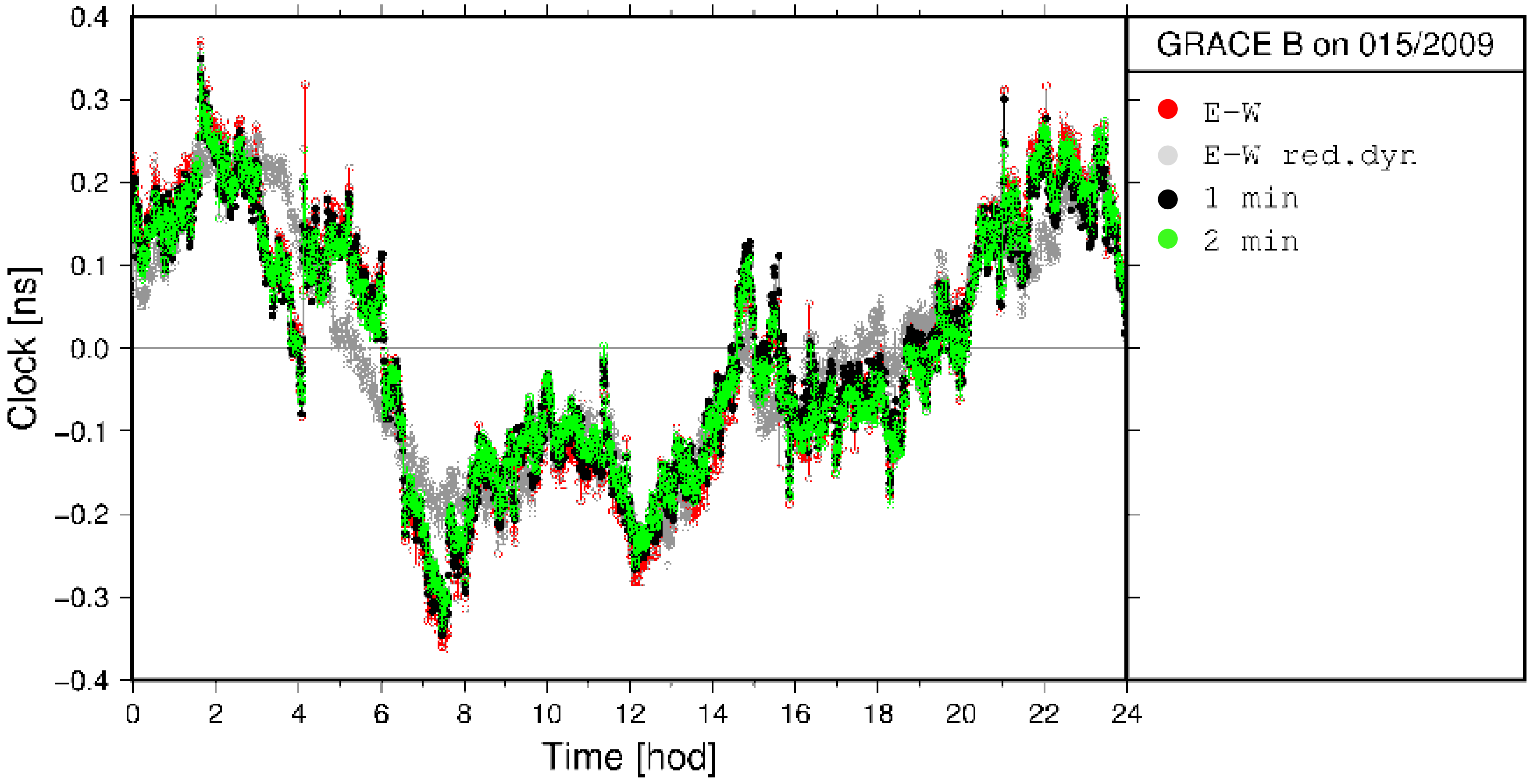
Clock modelling for kinematic LEO POD



Clock modelling for kinematic LEO POD



Clock modelling for kinematic LEO POD



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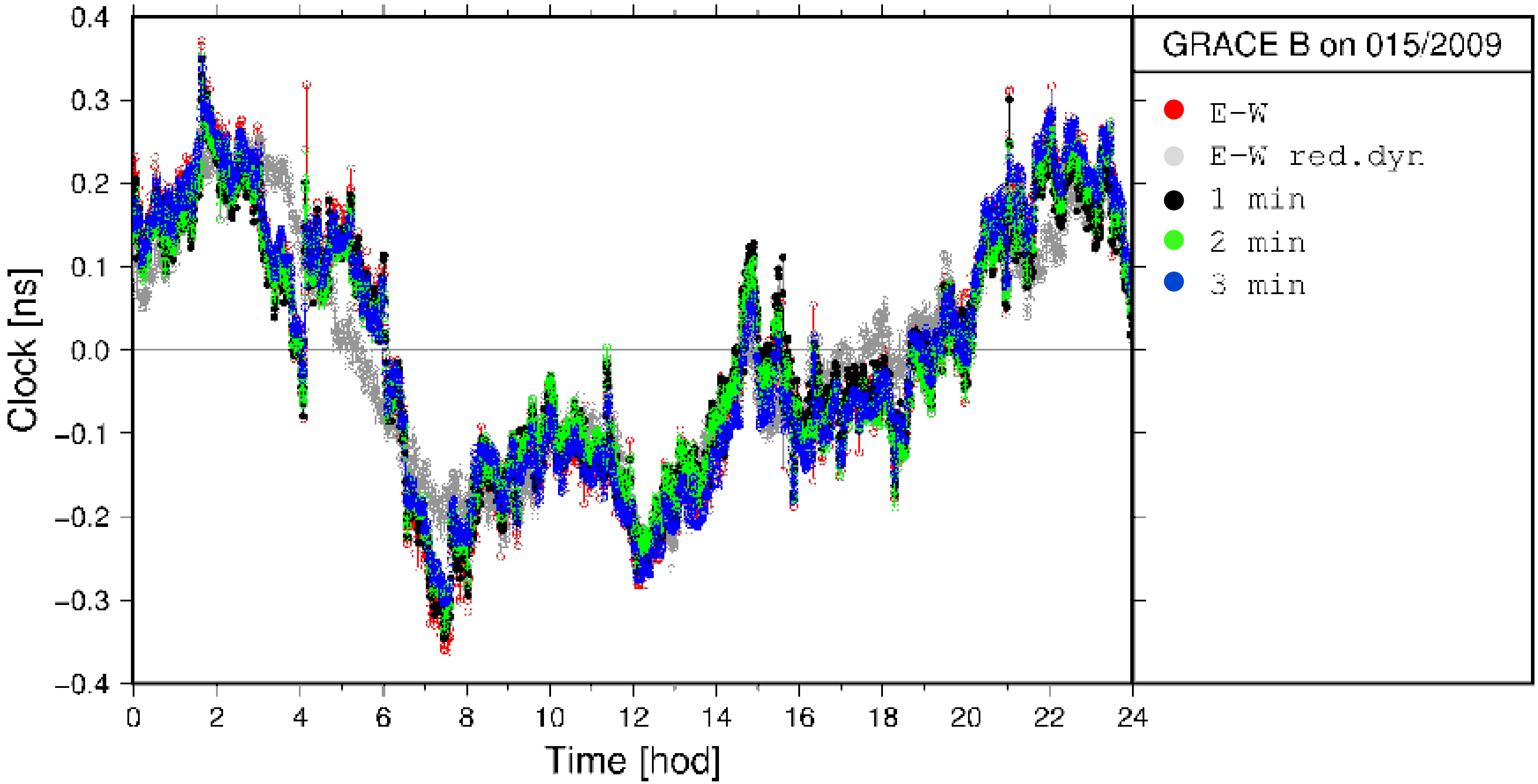

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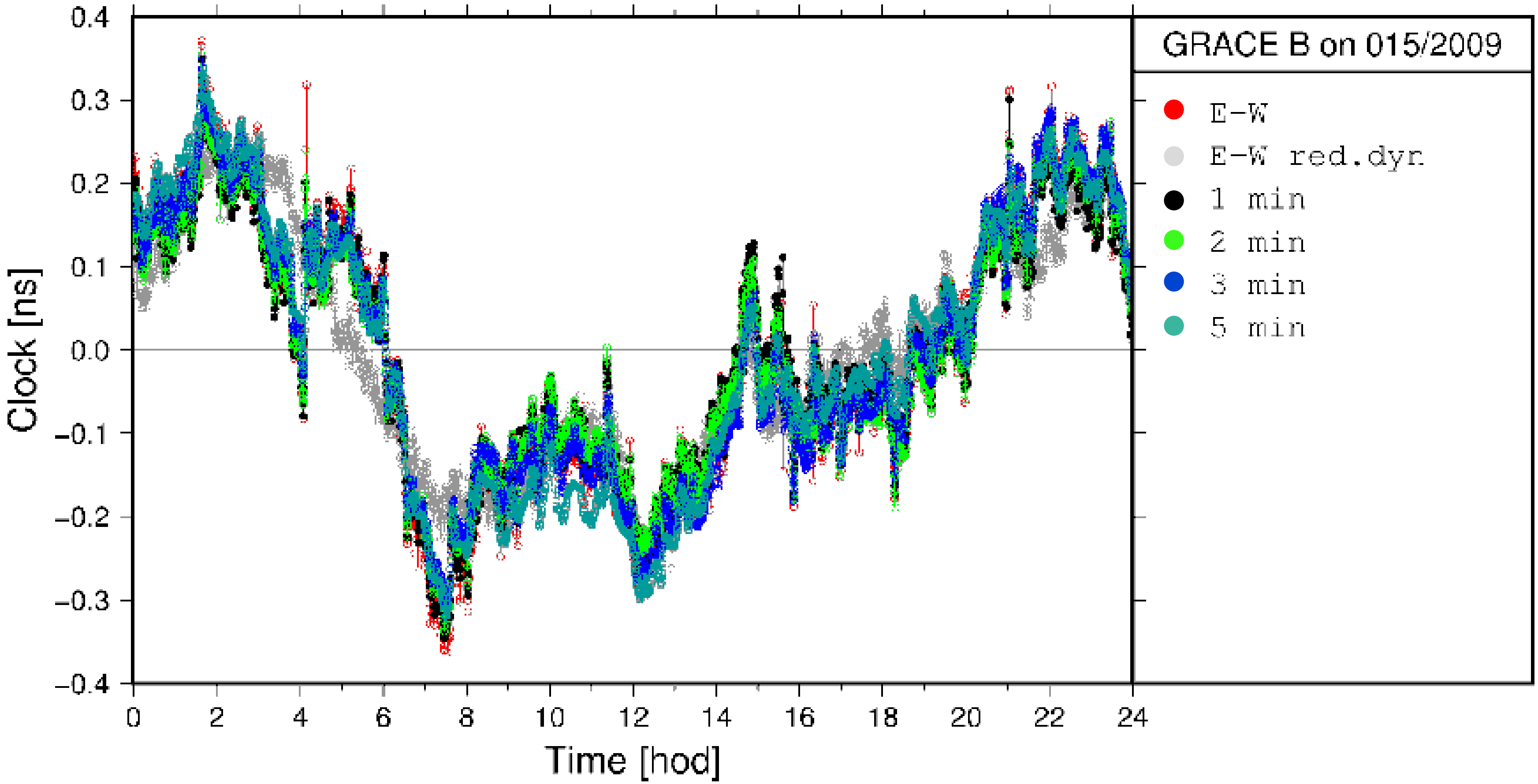

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Sentinel 3-A receiver clock assessment

From the corrected (jumps) receiver clock estimates a quadratic model has been subtracted.

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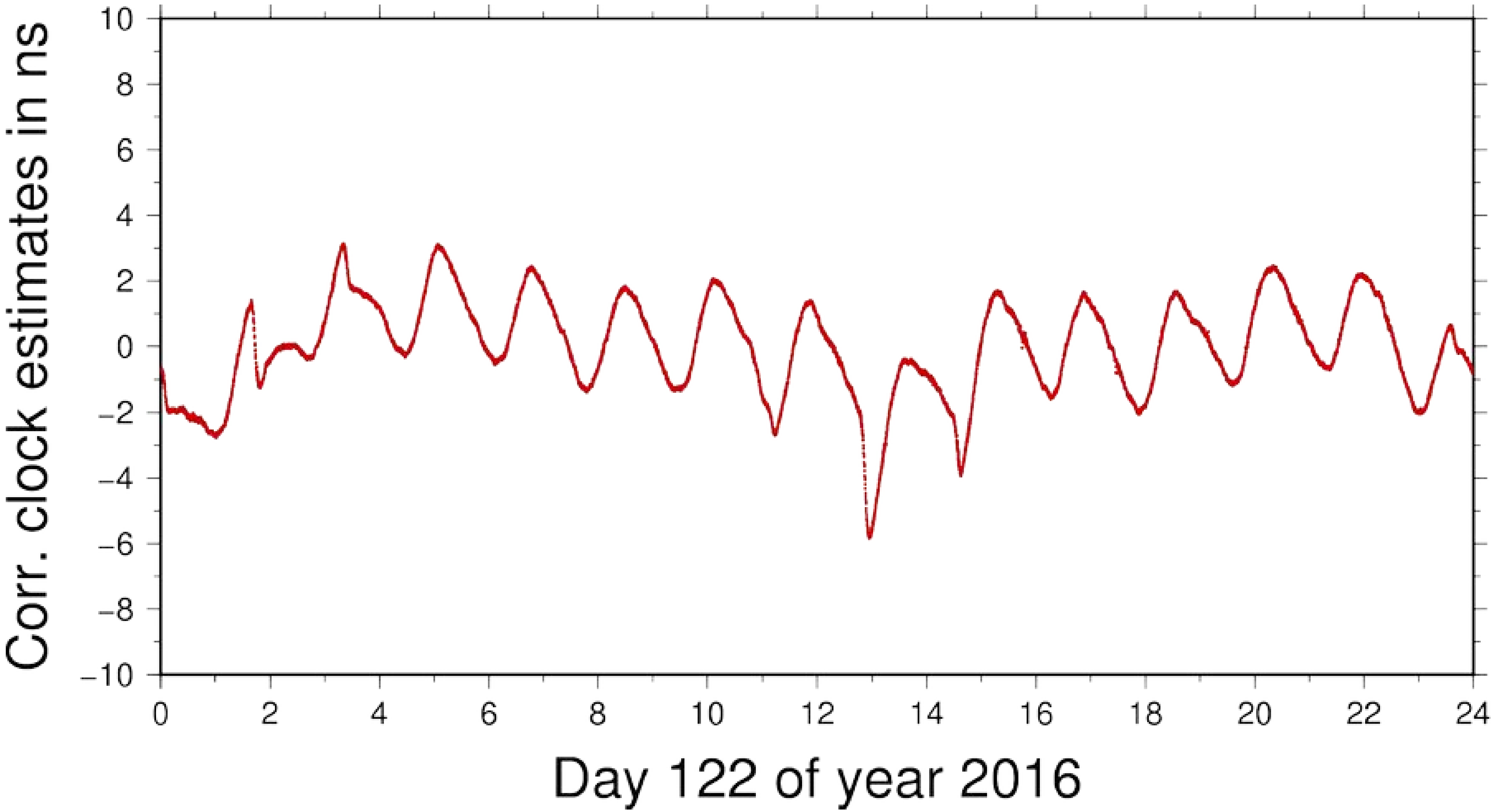
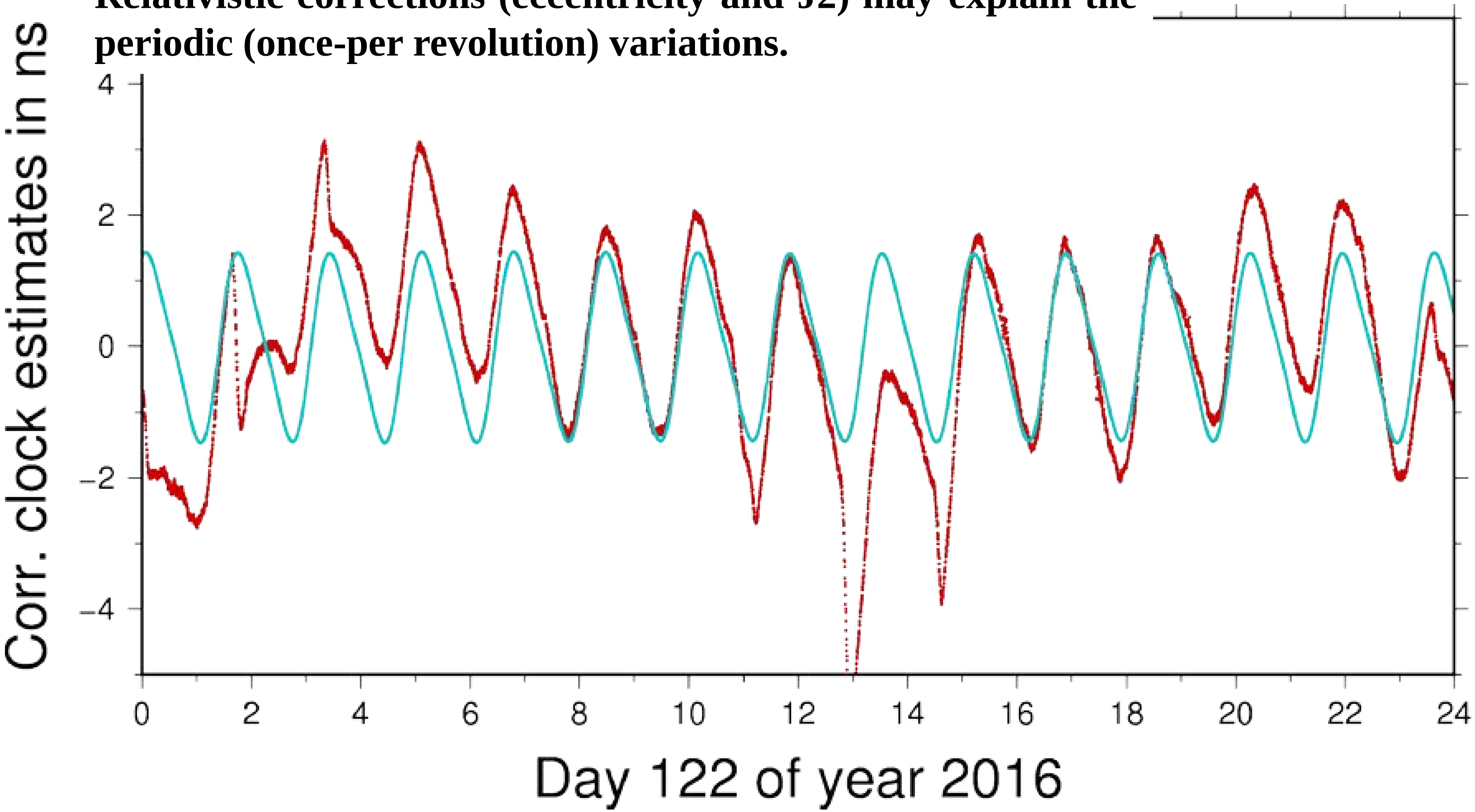
Sentinel 3-A receiver clock assessment



From the corrected (jumps) receiver clock estimates a quadratic model has been subtracted.

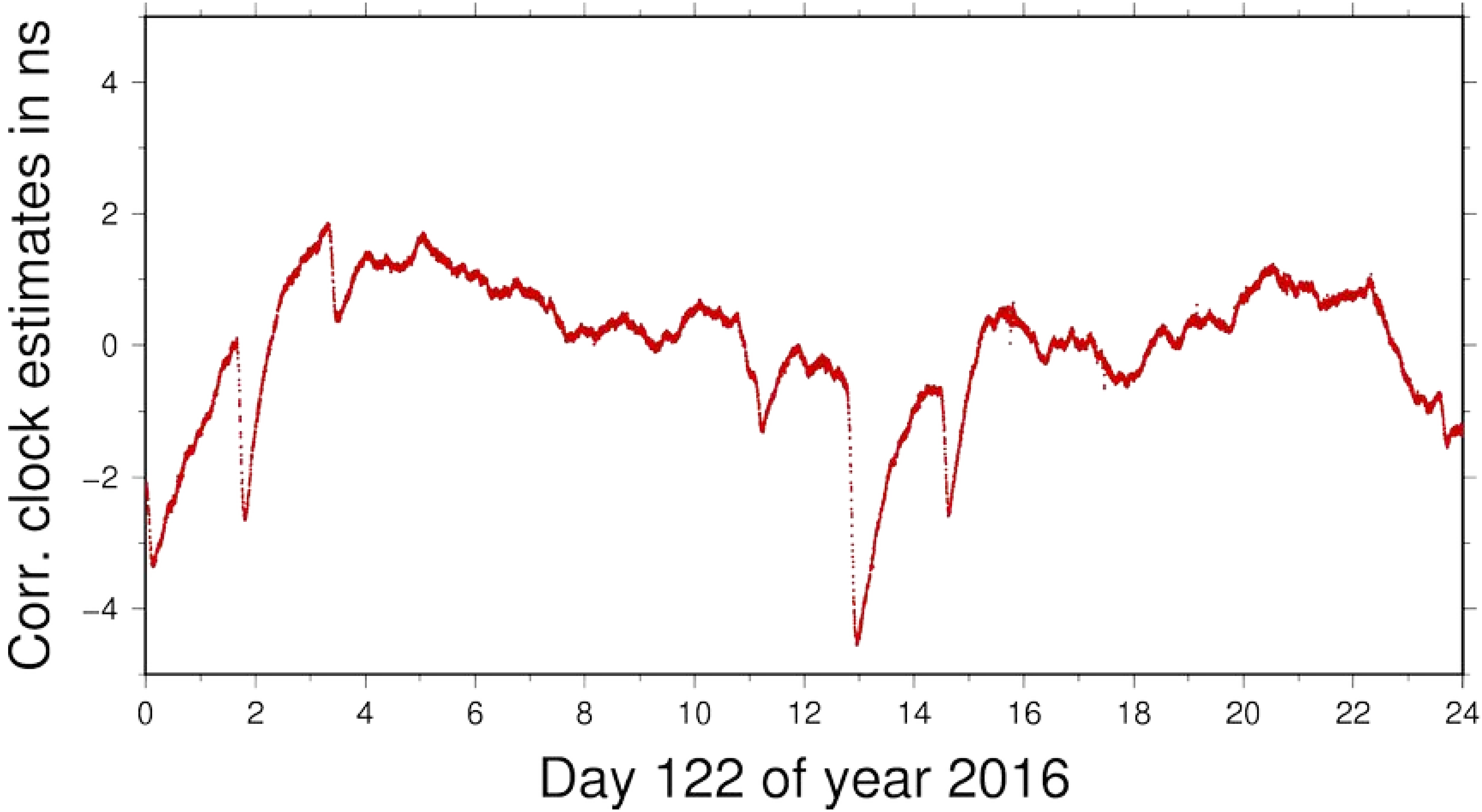
Sentinel 3-A receiver clock assessment

Relativistic corrections (eccentricity and J2) may explain the periodic (once-per revolution) variations.



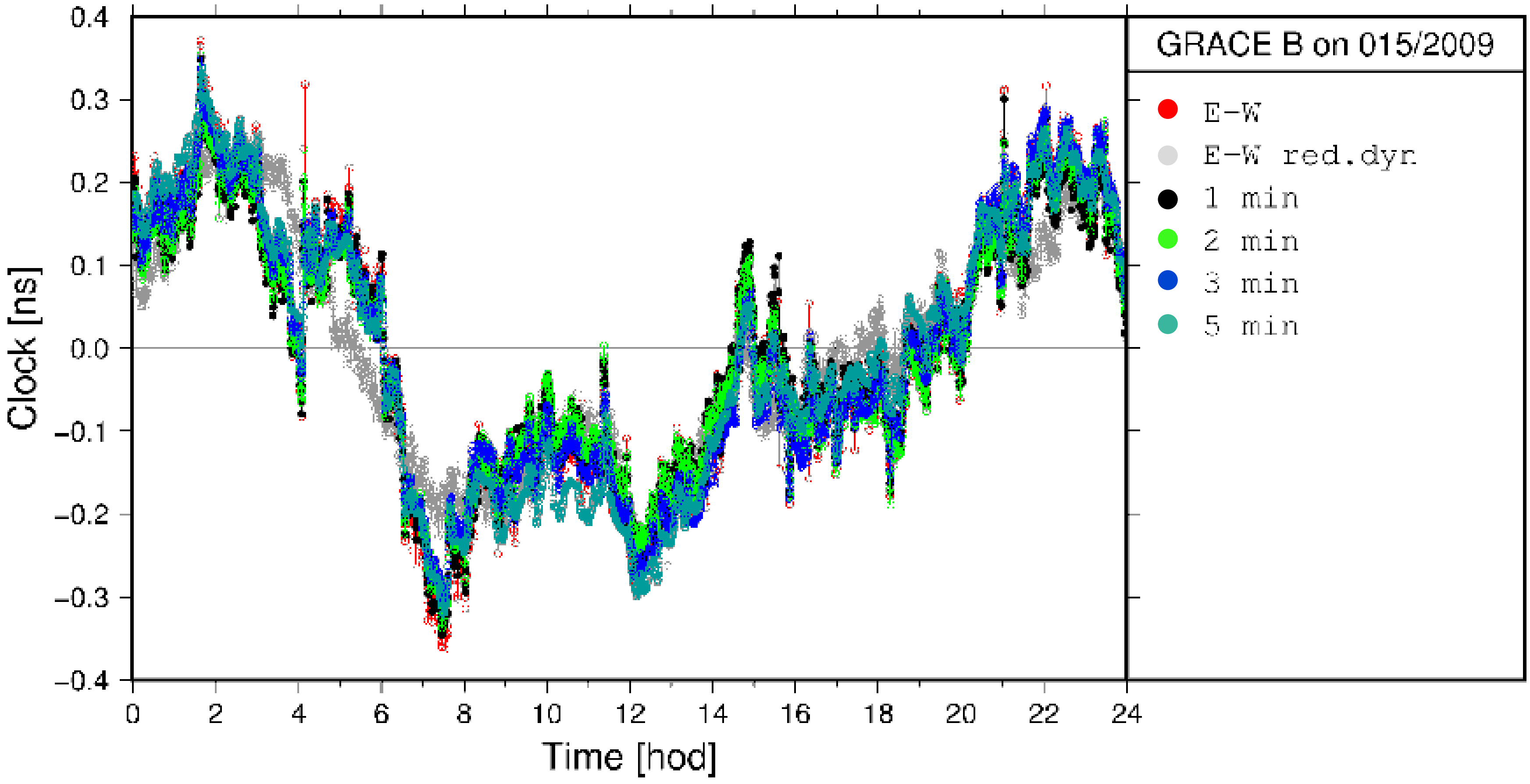
From the corrected (jumps) receiver clock estimates a quadratic model has been subtracted.

Sentinel 3-A receiver clock assessment

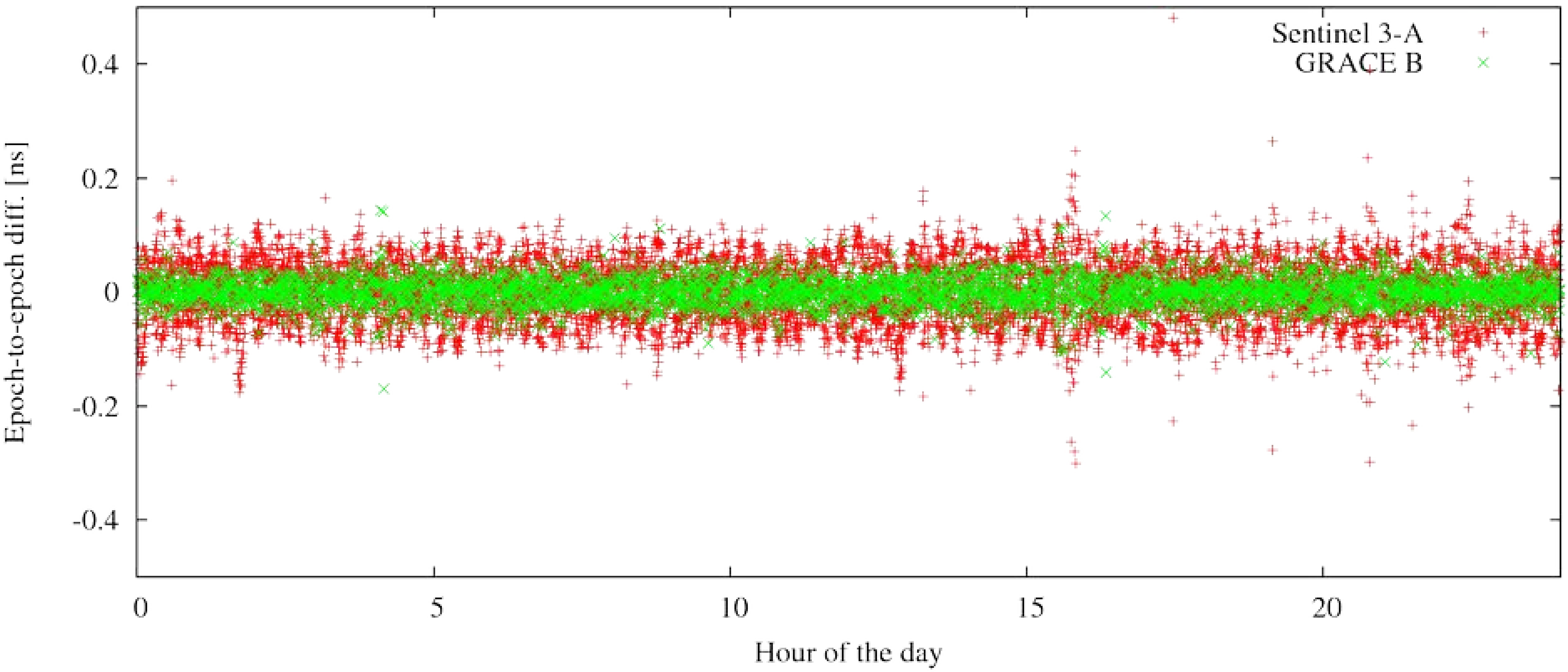


From the corrected (jumps and relativistic effects) receiver clock estimates a quadratic model has been subtracted.

Sentinel 3-A and GRCE B receiver clock comparison



Sentinel 3-A and GRCE B receiver clock comparison



Summary

- Based on different scenarios, model using GPS+Gal observations from big network, with linear clock model applied shows the best results in terms of orbit modelling and SLR analysis.
- The clock quality is reflected in the solutions.
- Analysis showed apparent β angle dependency indicating SRP model deficiencies.
- Comparison between Sentinel 3-A and GRACE receiver clock corrections shows potential for clock modelling.