Moving from GPS to multi-GNSS: challenges for users, applications, and software

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Outline

Galileo est dans l'air. . .

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- Review the current situation: GPS and GLONASS

  GPS-only or combination of GPS/GLONASS?

  What needs to be considered? Where are the limitations?

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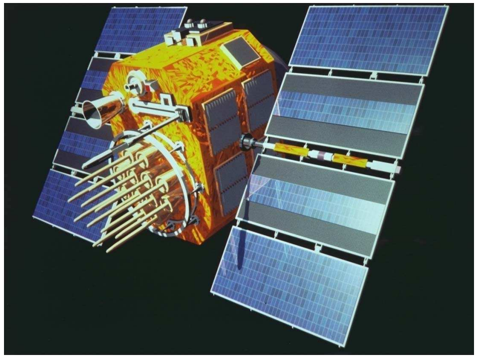
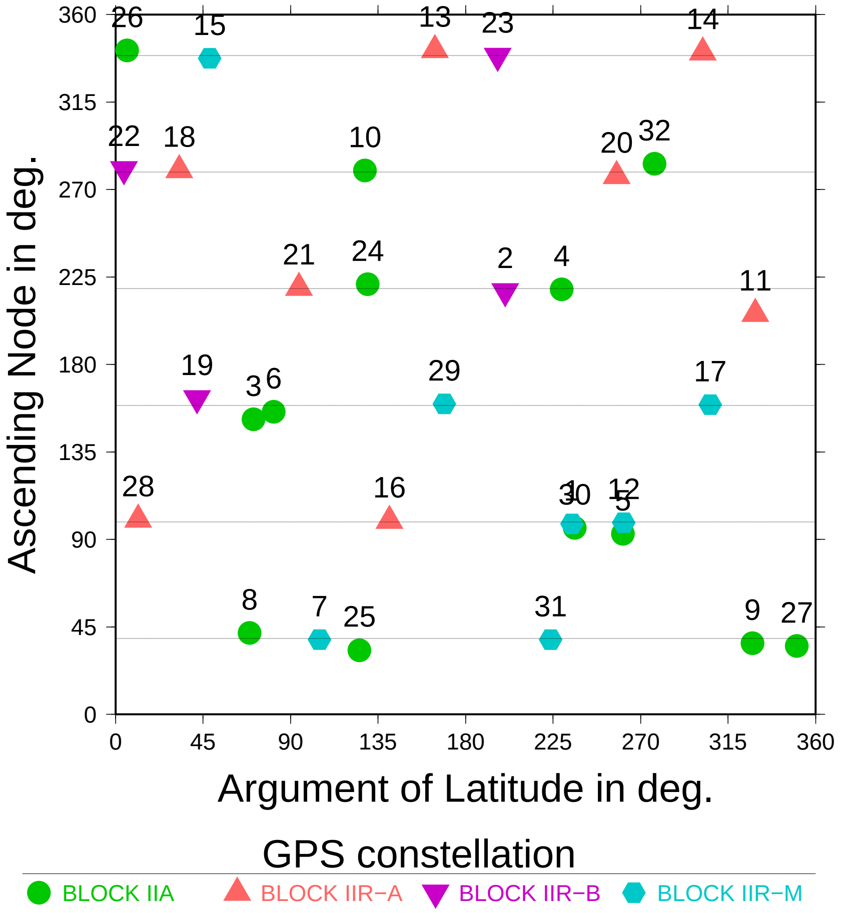
Moving from GPS to multi–GNSS:
challenges for users, applications, and software

GPS: Global Positioning System



- The current GPS constellation consists of 31 active satellites from four different types.



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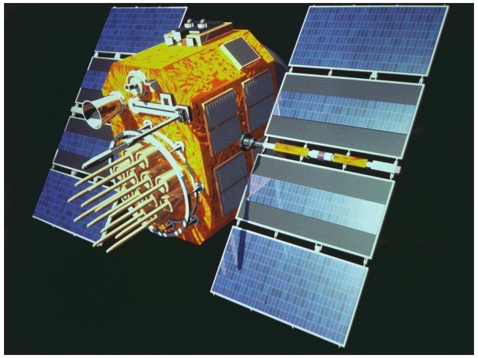

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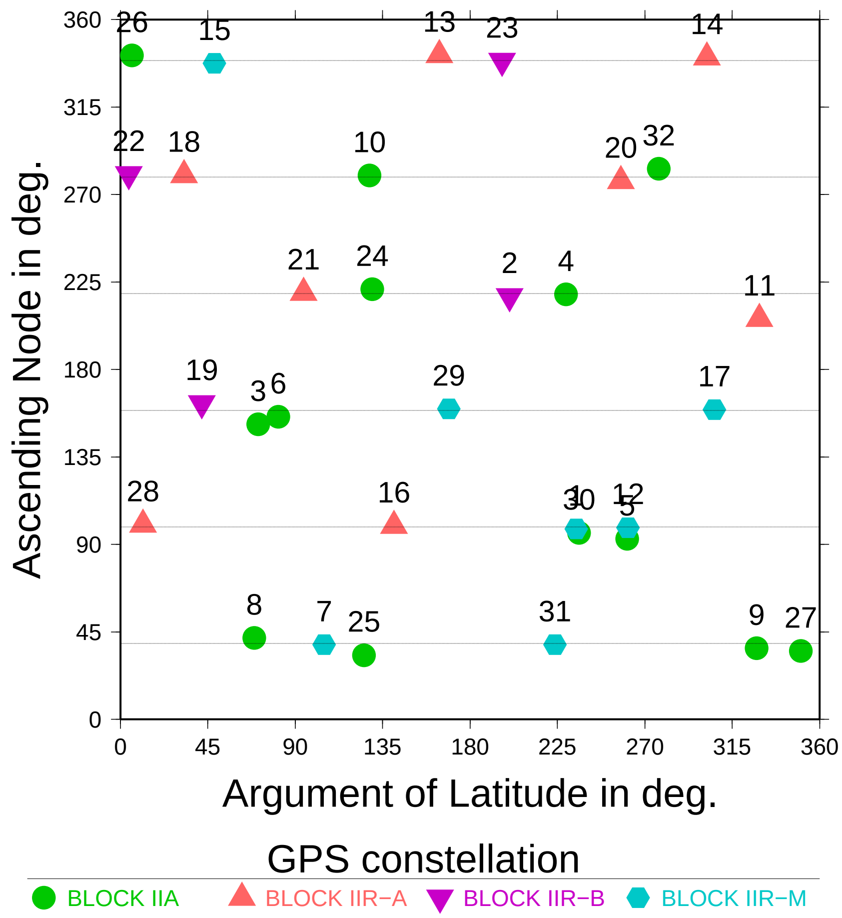
- Available observations:
  - code measurements (P1, P2, C1, C2*)
  - dual frequency carrier phase:
    L1C, L1P, L1N as well as
    L2C, L2D, L2S, L2L, L2X, L2P, L2N



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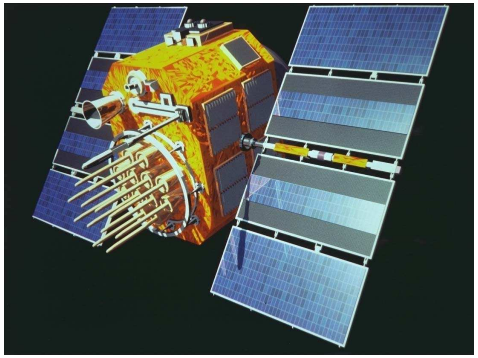

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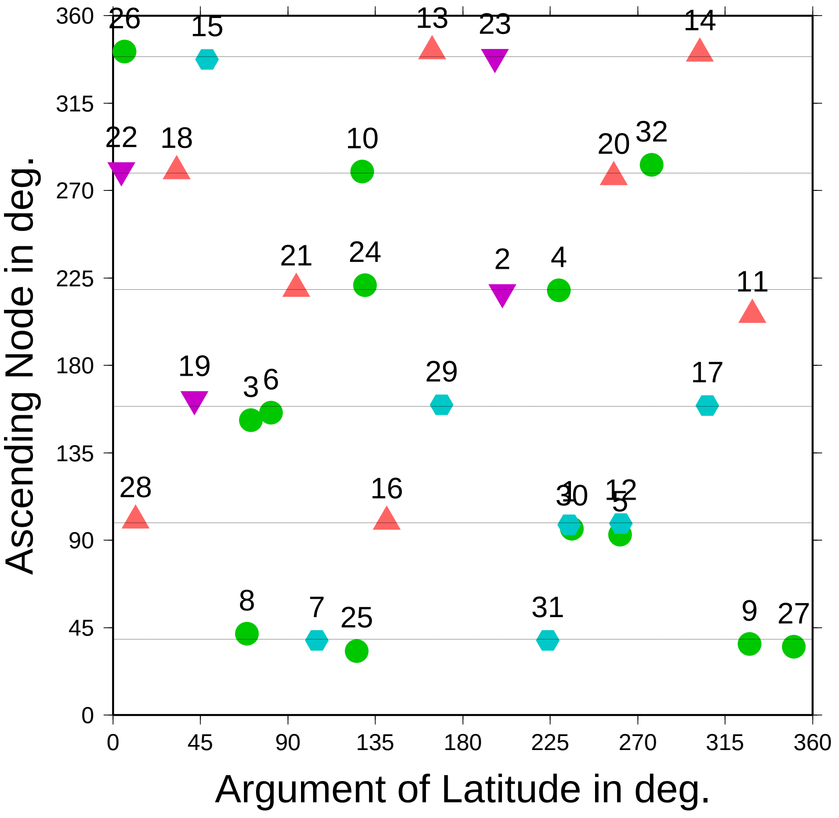
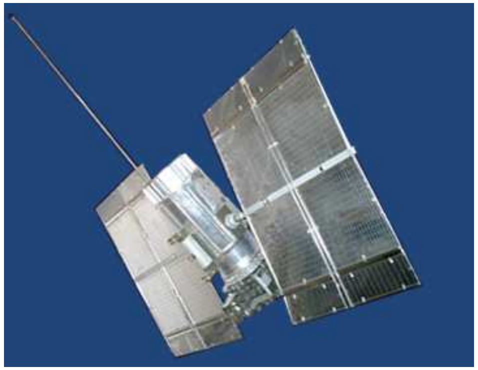
  - quarter cycle between L2P and L2C

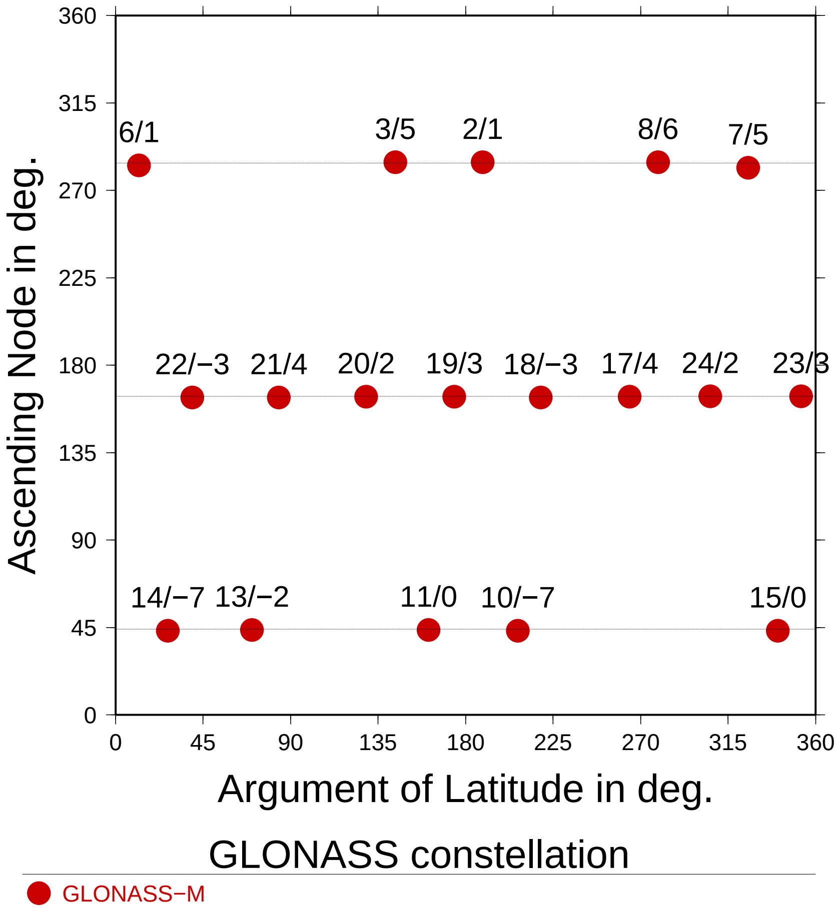


GPS constellation

GNSS: Current Situation

GLONASS: Глобальная навигационная спутниковая система





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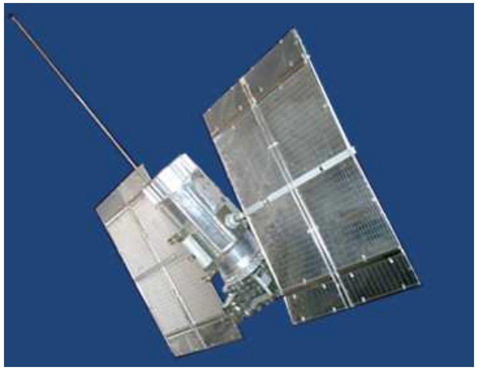

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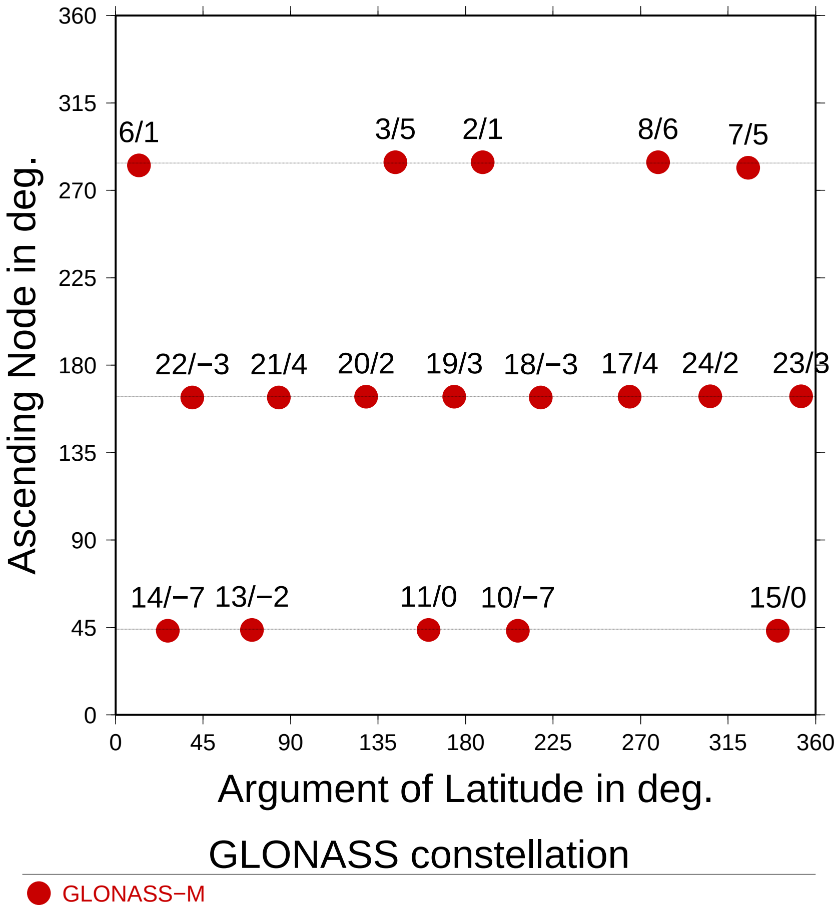
  - each satellites uses its own frequency



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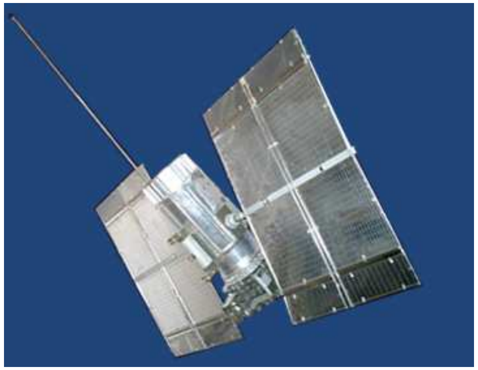

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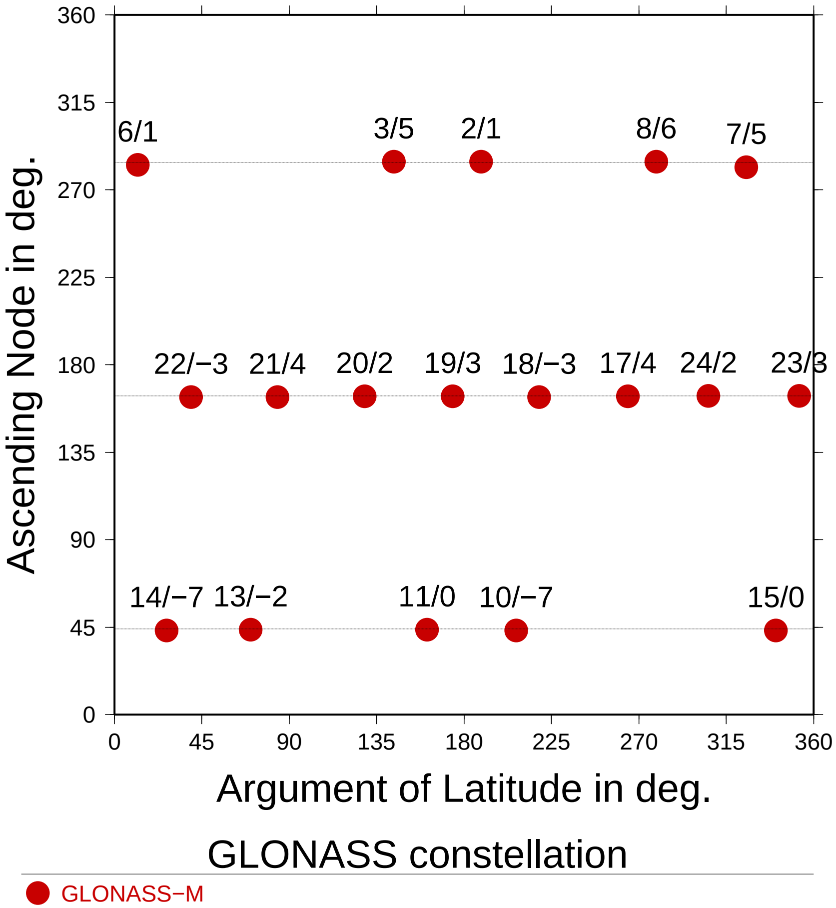

GLONASS constellation

Combination of GPS and GLONASS

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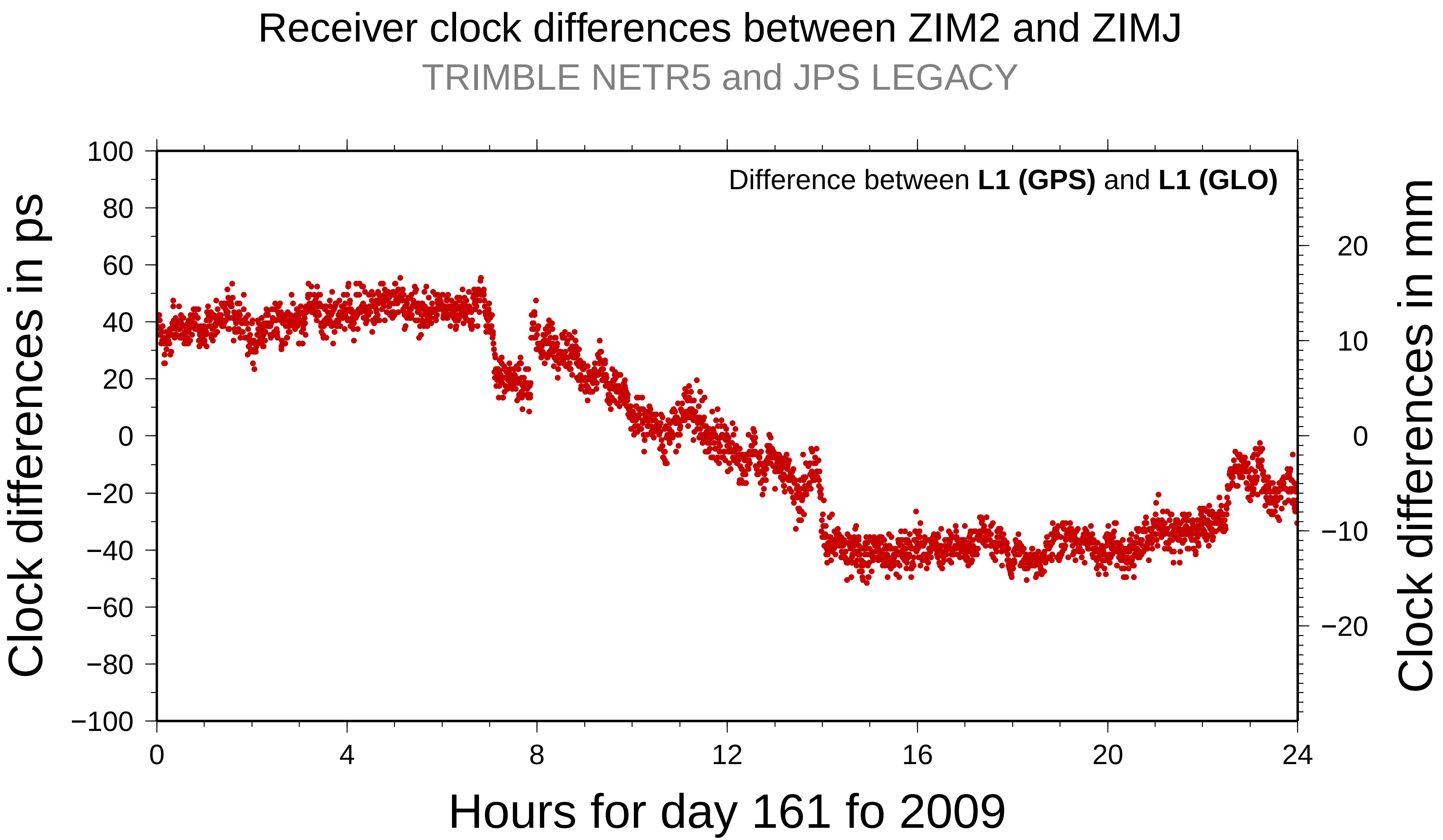
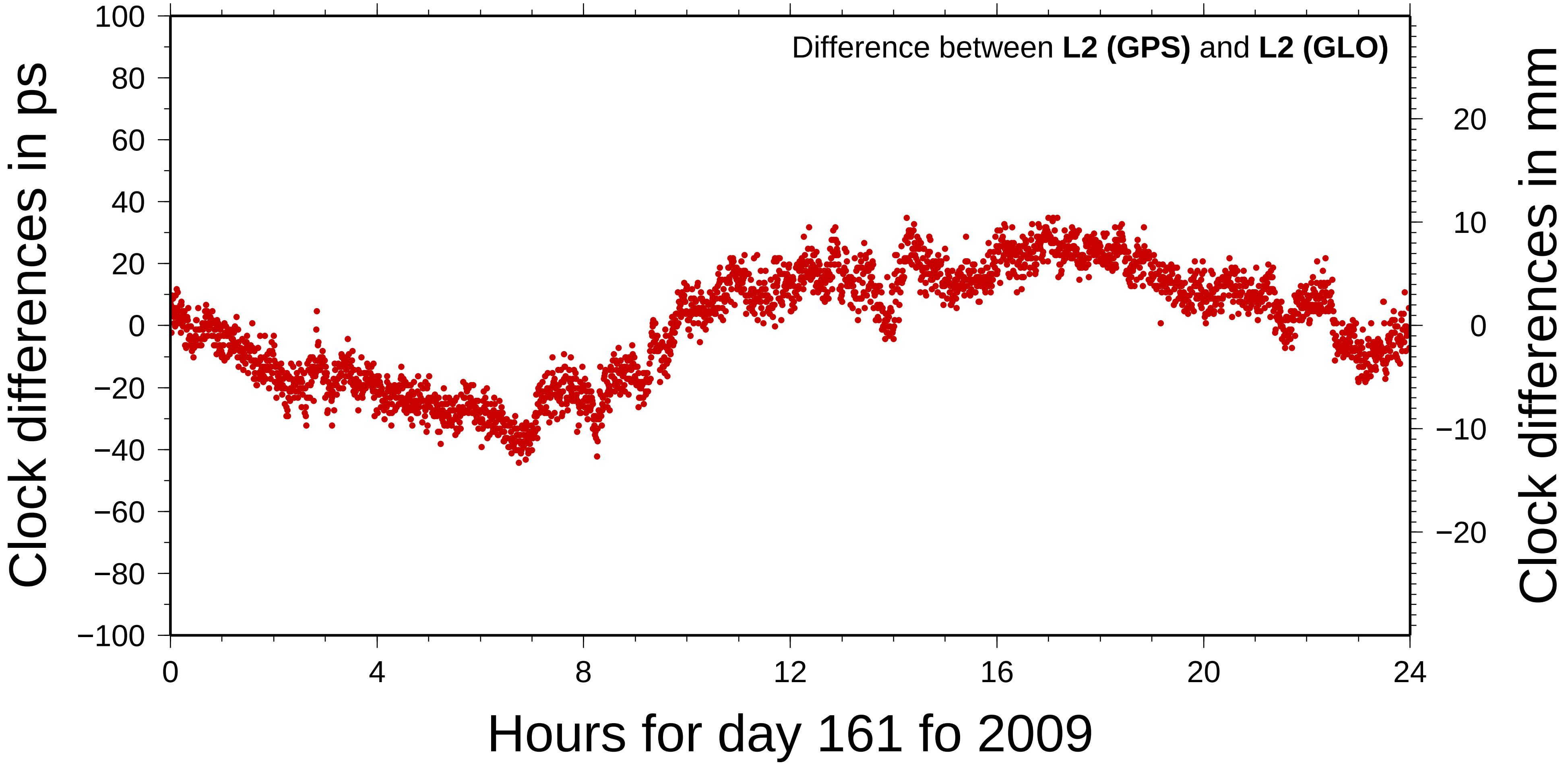


phase–only zero–difference network solutions

Receiver Intersystem Biases

Receiver clock differences between ZIM2 and ZIMJ

TRIMBLE NETR5 and JPS LEGACY



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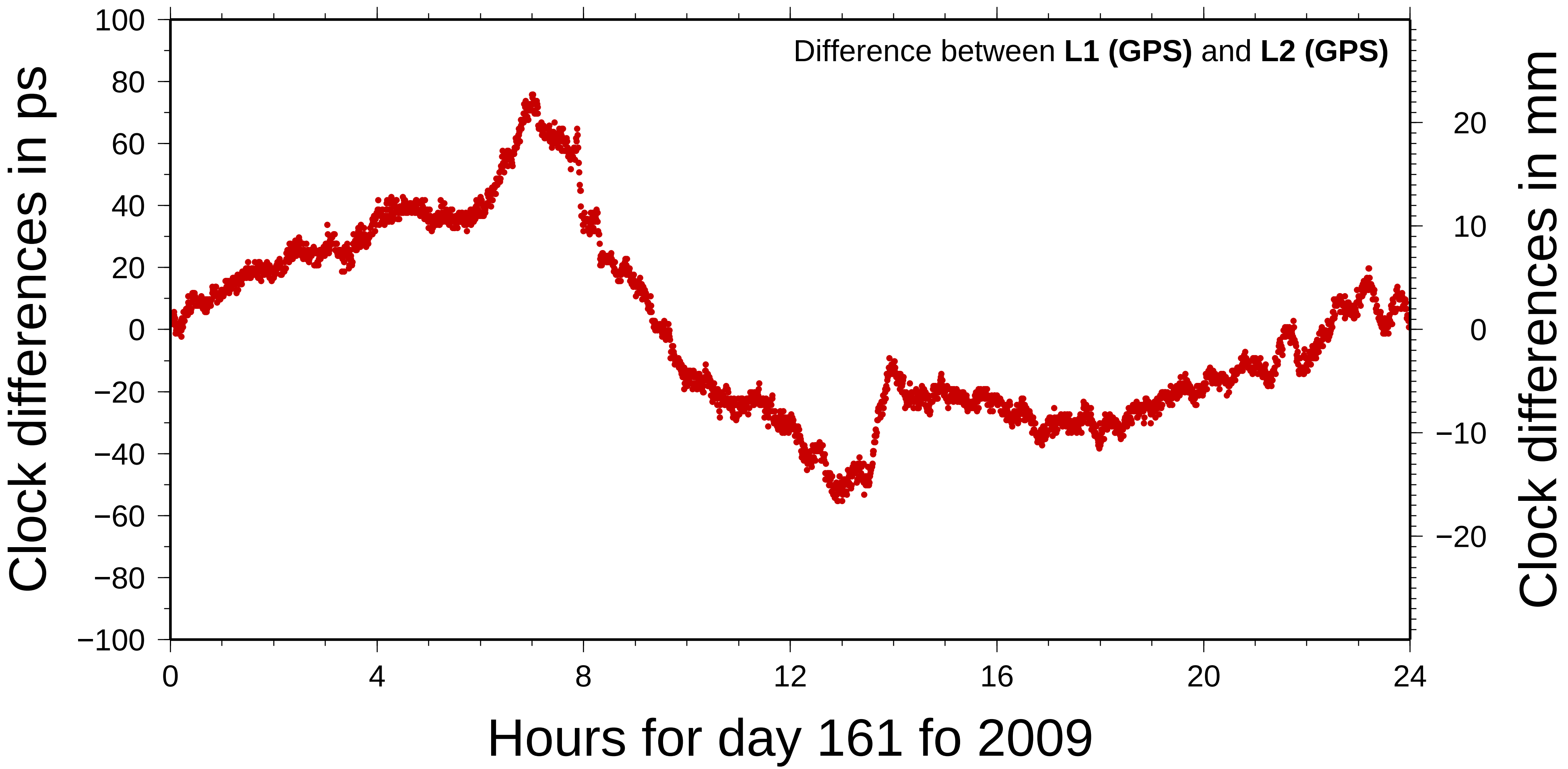

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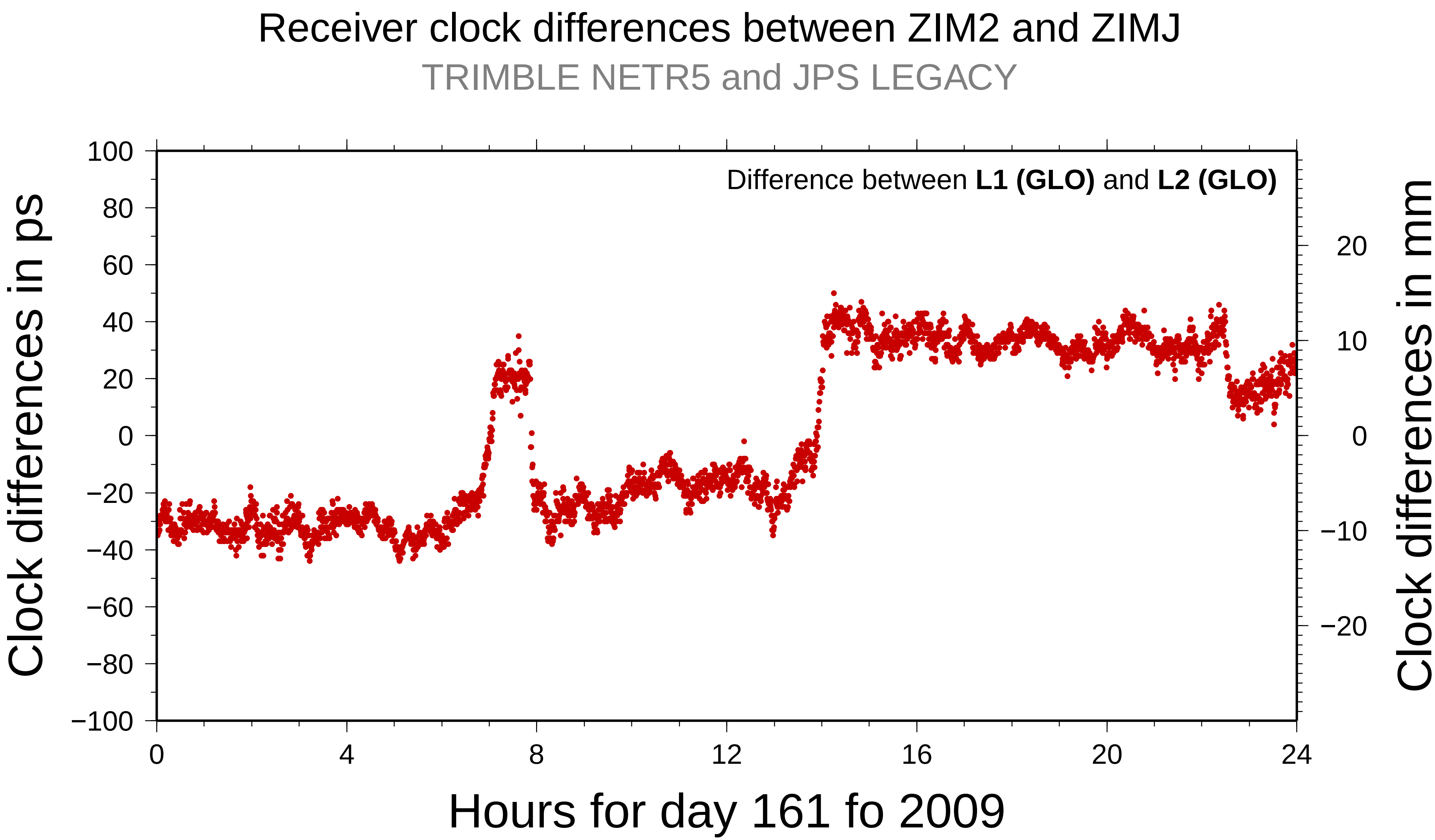

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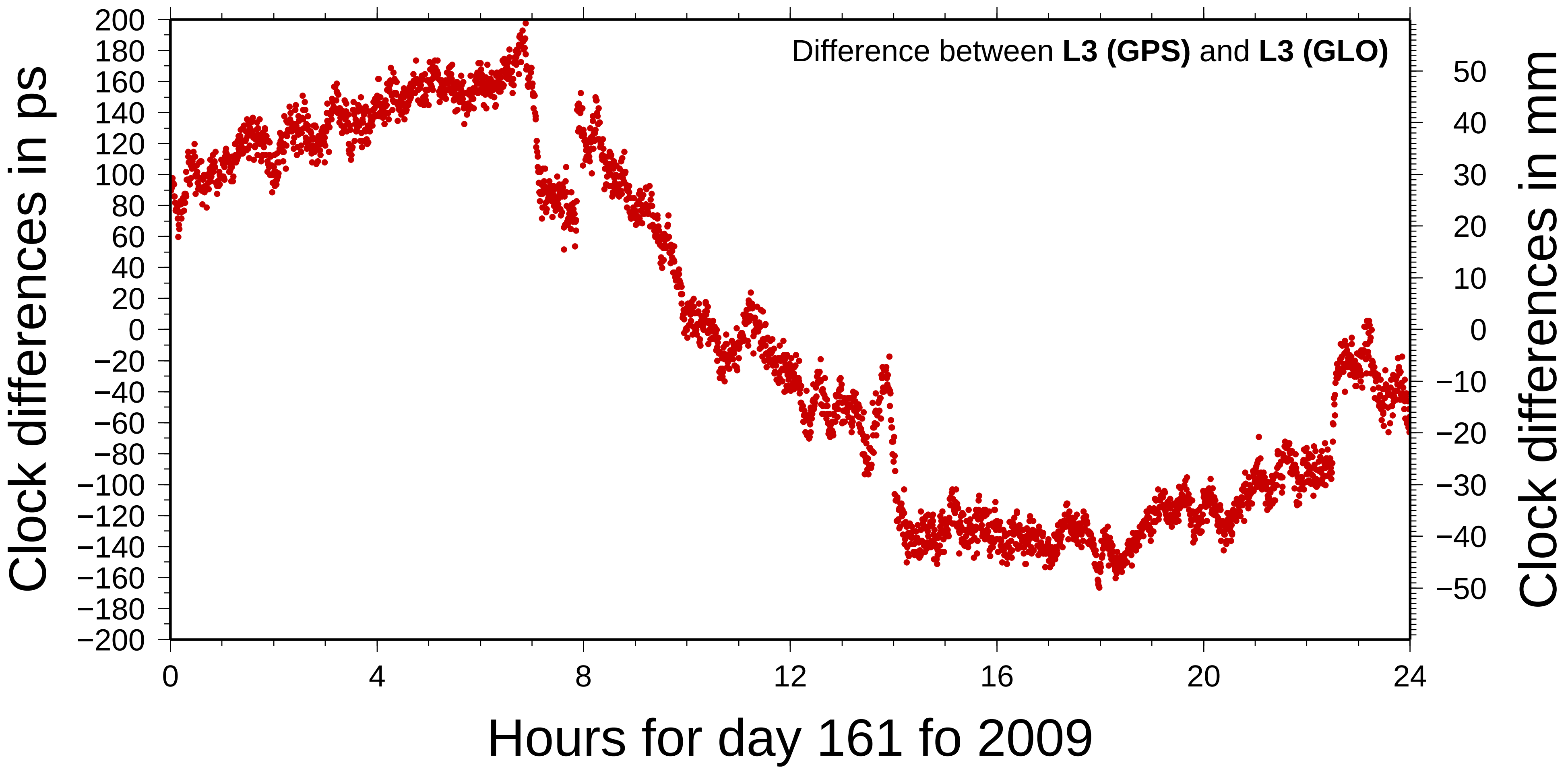

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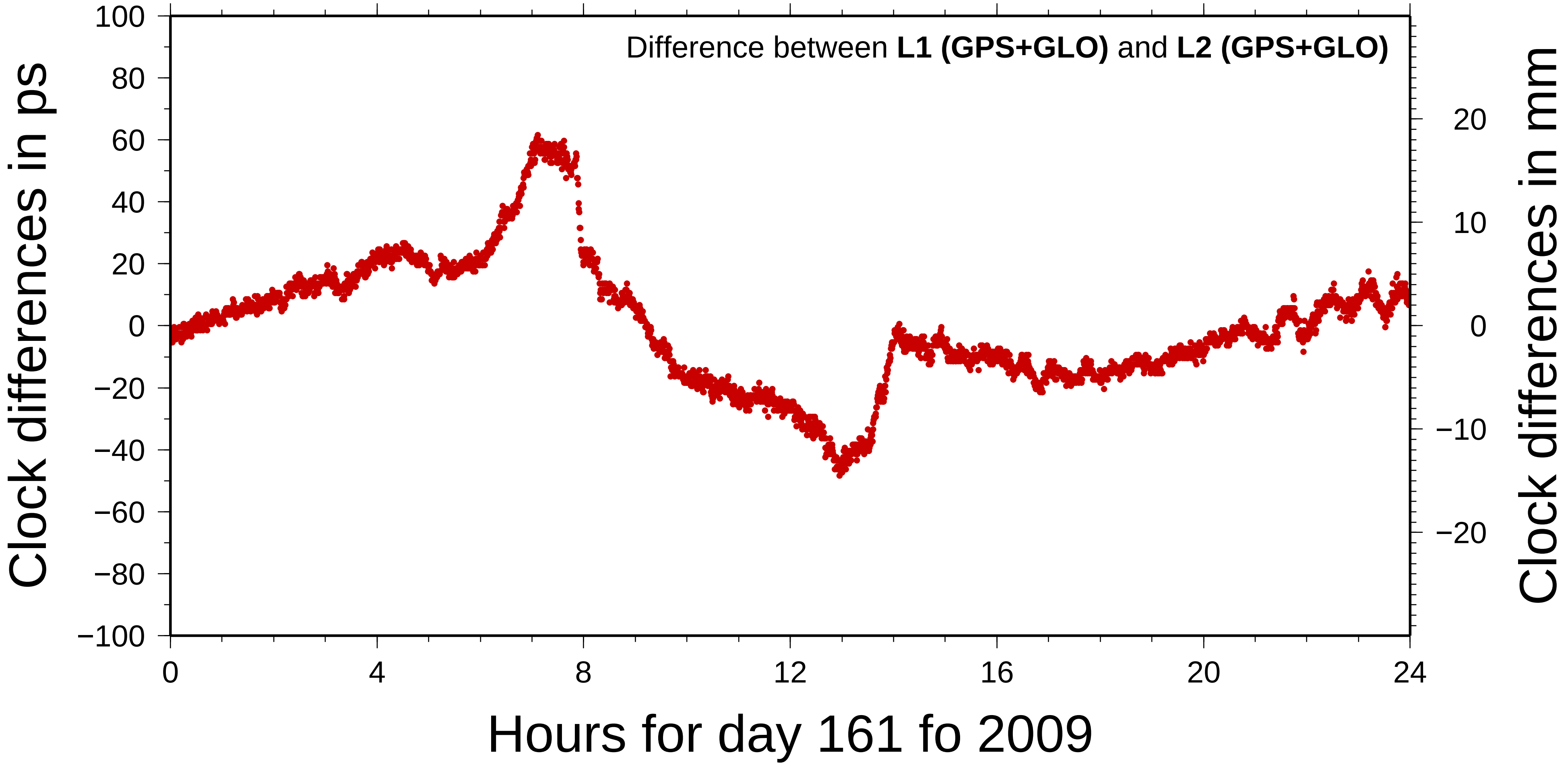

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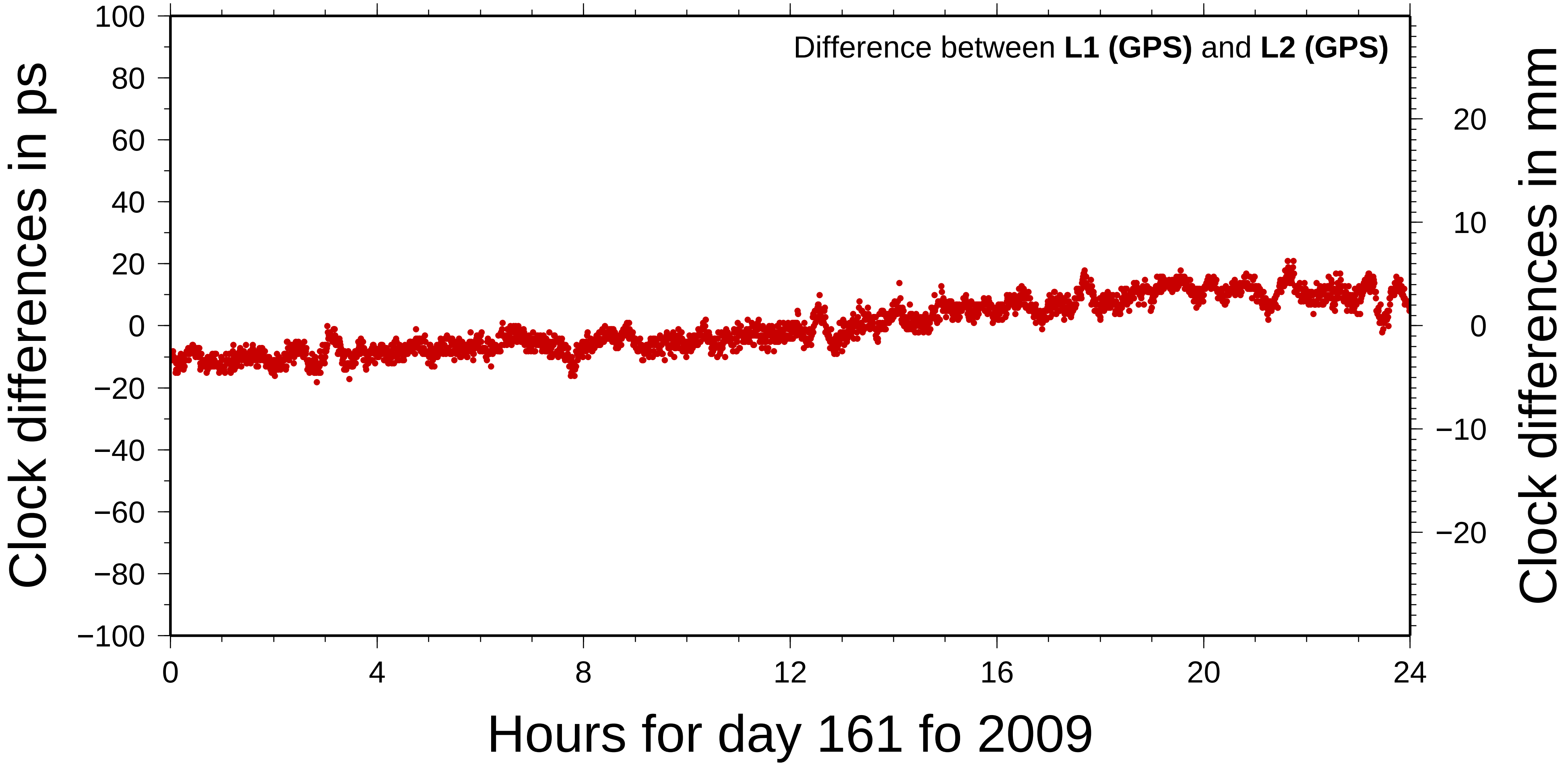

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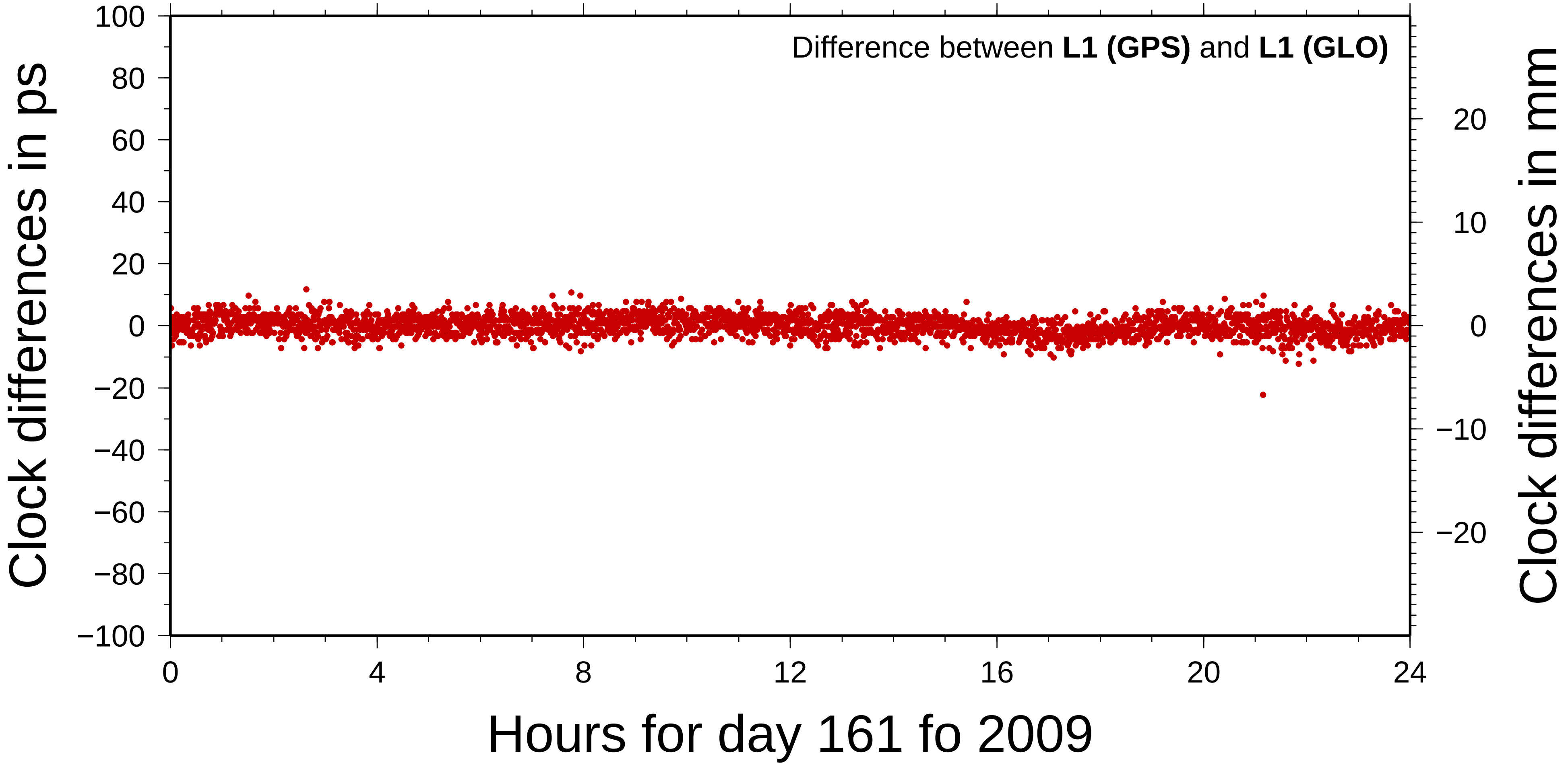
Receiver Intersystem Biases

Receiver clock differences between UNB3 and UNBN

TRIMBLE NETR5 and NOV OEMV3, antenna sharing



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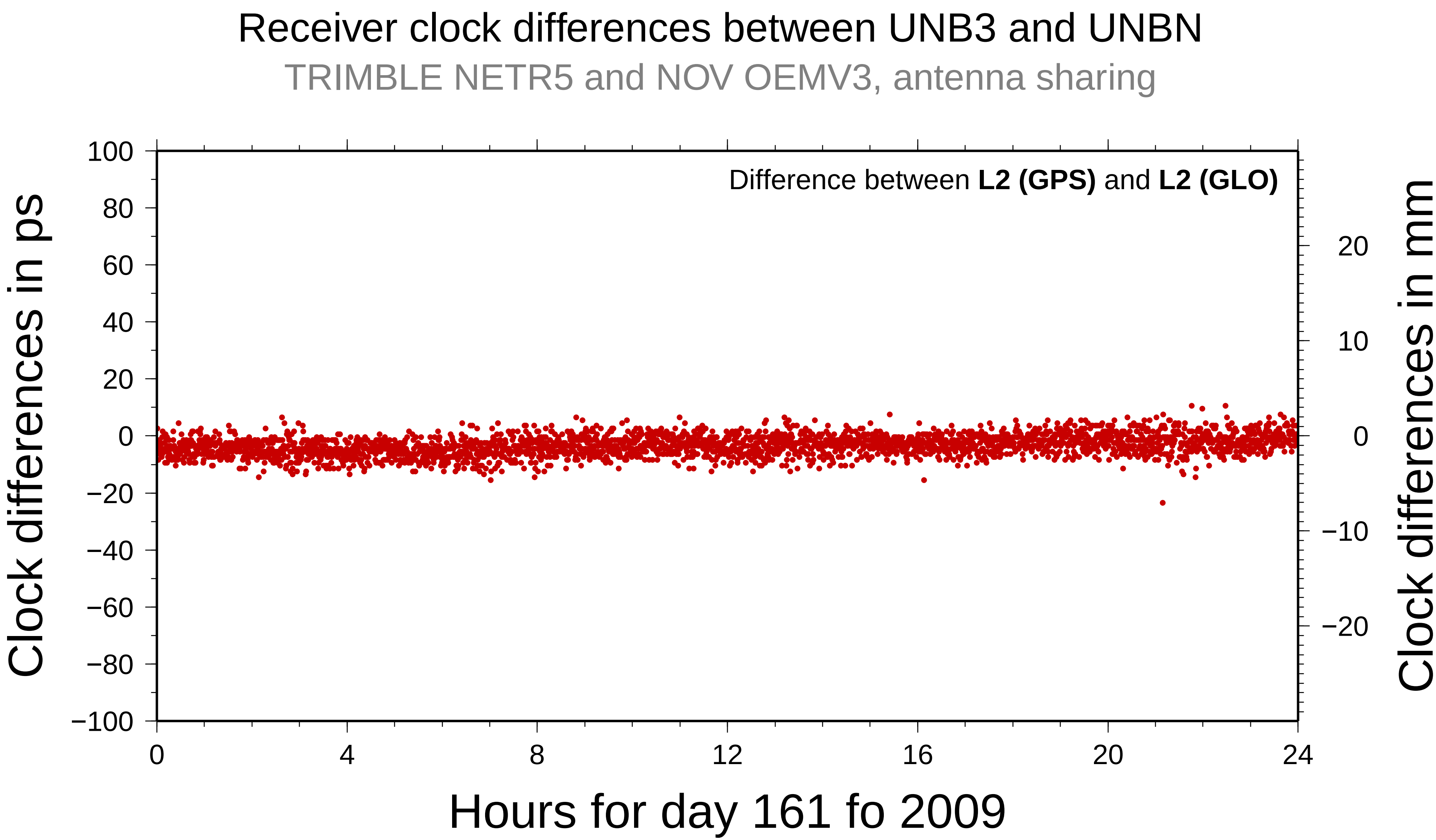

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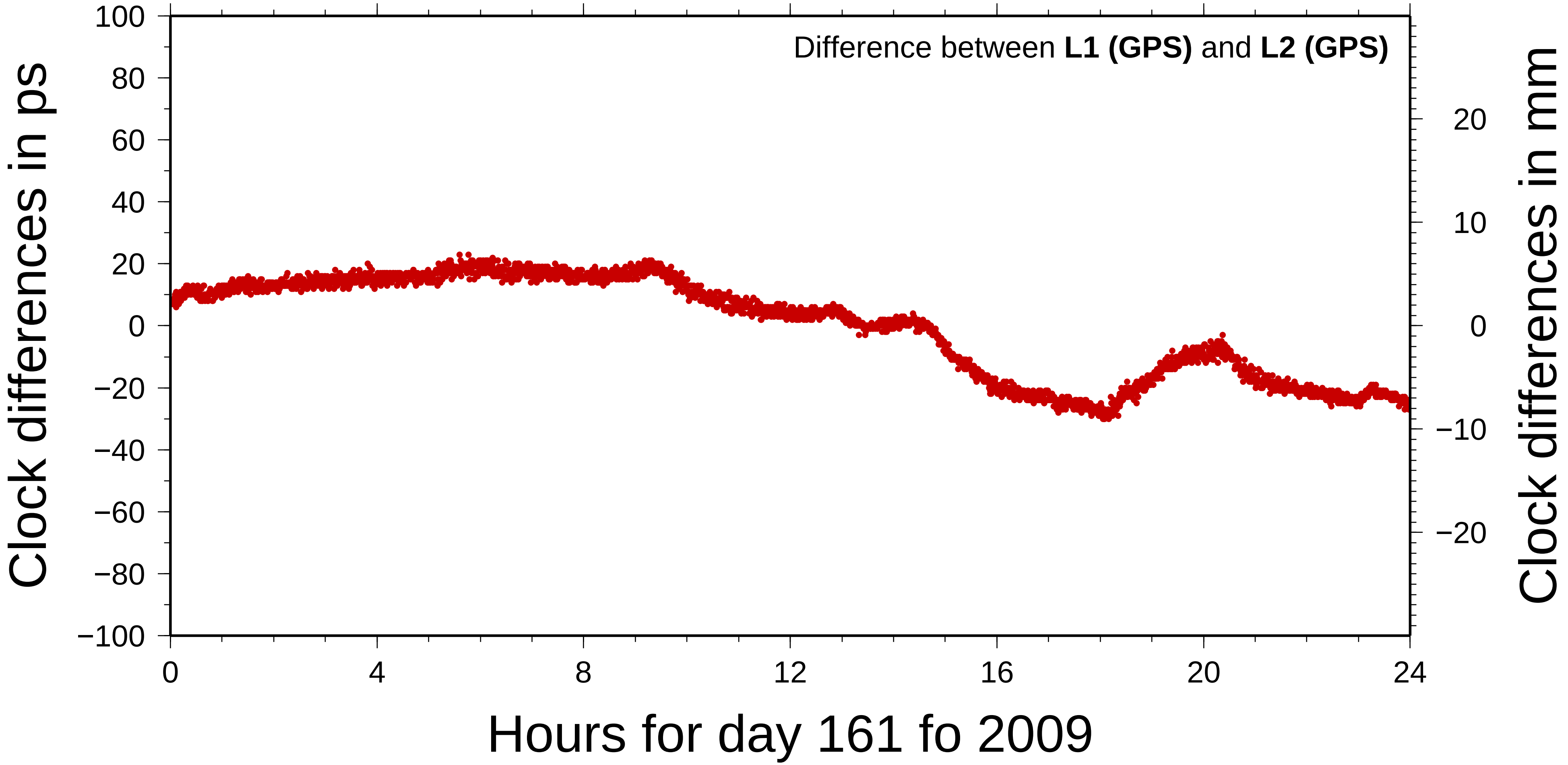

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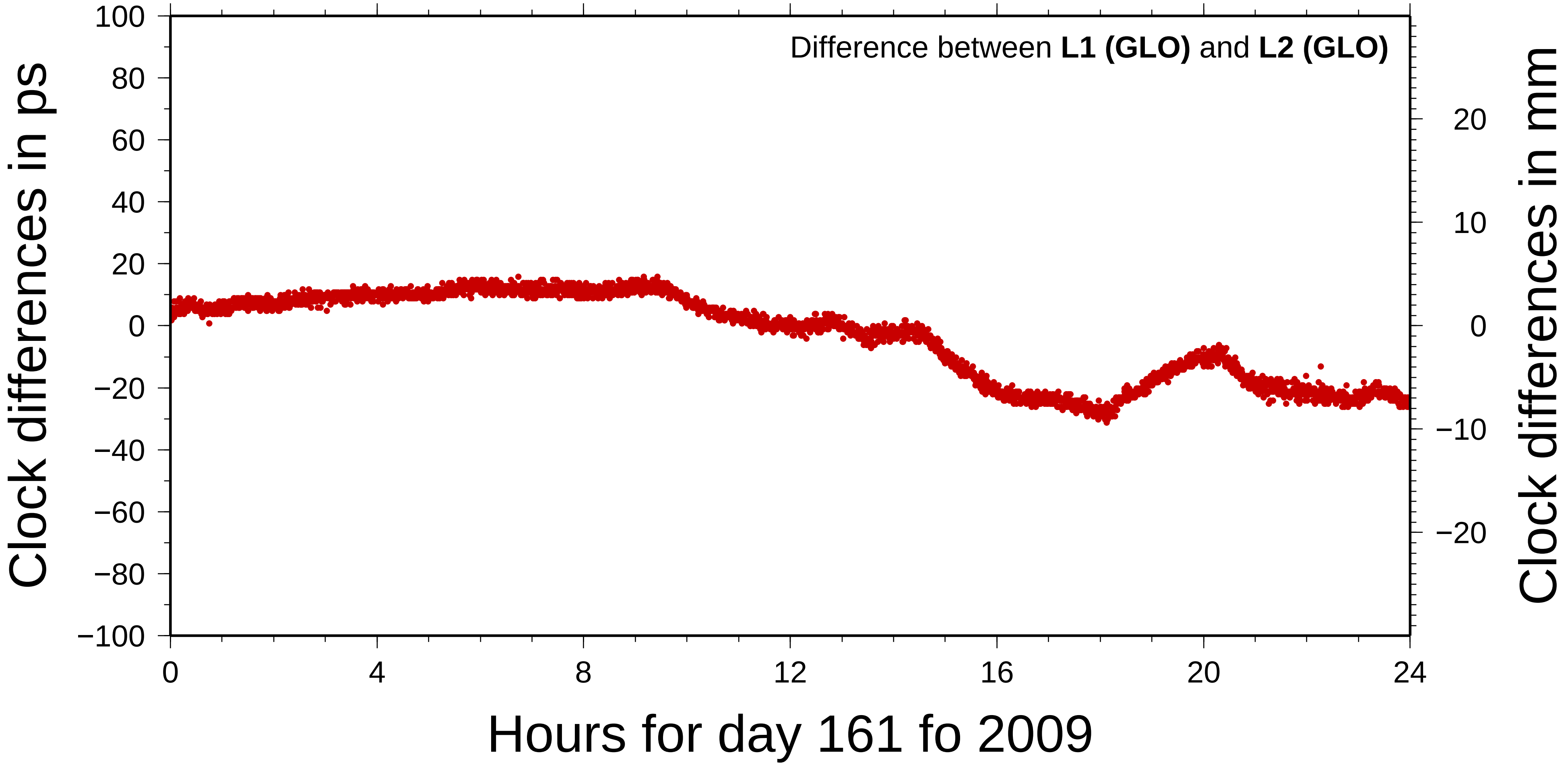

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What will be the future?

- GPS: Third frequency
  G01 (launch March 2009) has a demonstration signal for L5.

GNSS: Expected Developments

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  Five frequencies, with particially restricted access to the code measurements
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- Compass/Bejdou: Additional GNSS
  First satellites are in space, too. . .

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In future multi–GNSS receivers will provide a certain set of measurements from several systems.

What to do with these measurements in the processing?

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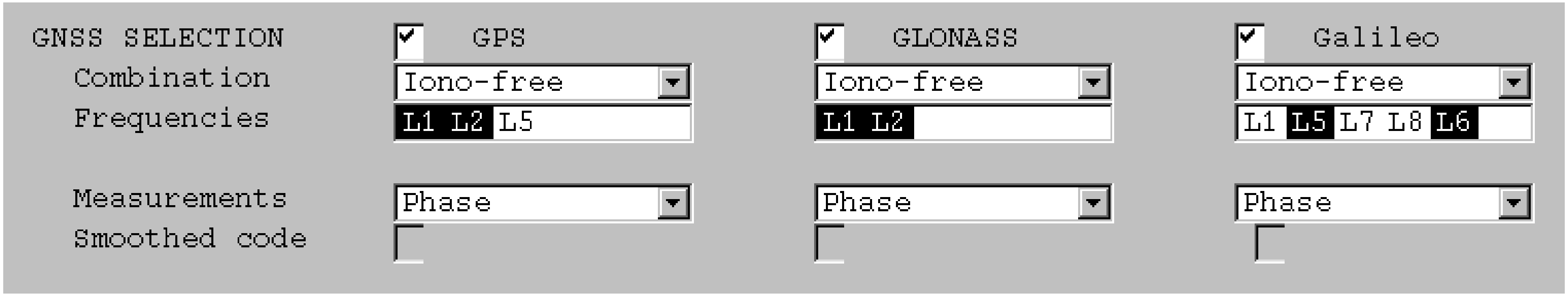
What to do with these measurements in the processing?

How to form an ionosphere–free LC the future?

- pre–select two frequencies per GNSS?
- pre–select two frequencies per GNSS and receiver type?
- make use of the third frequency of a subset of satellites?

Flexible handling of observation types is necessary:



Example: Bernese GNSS Software

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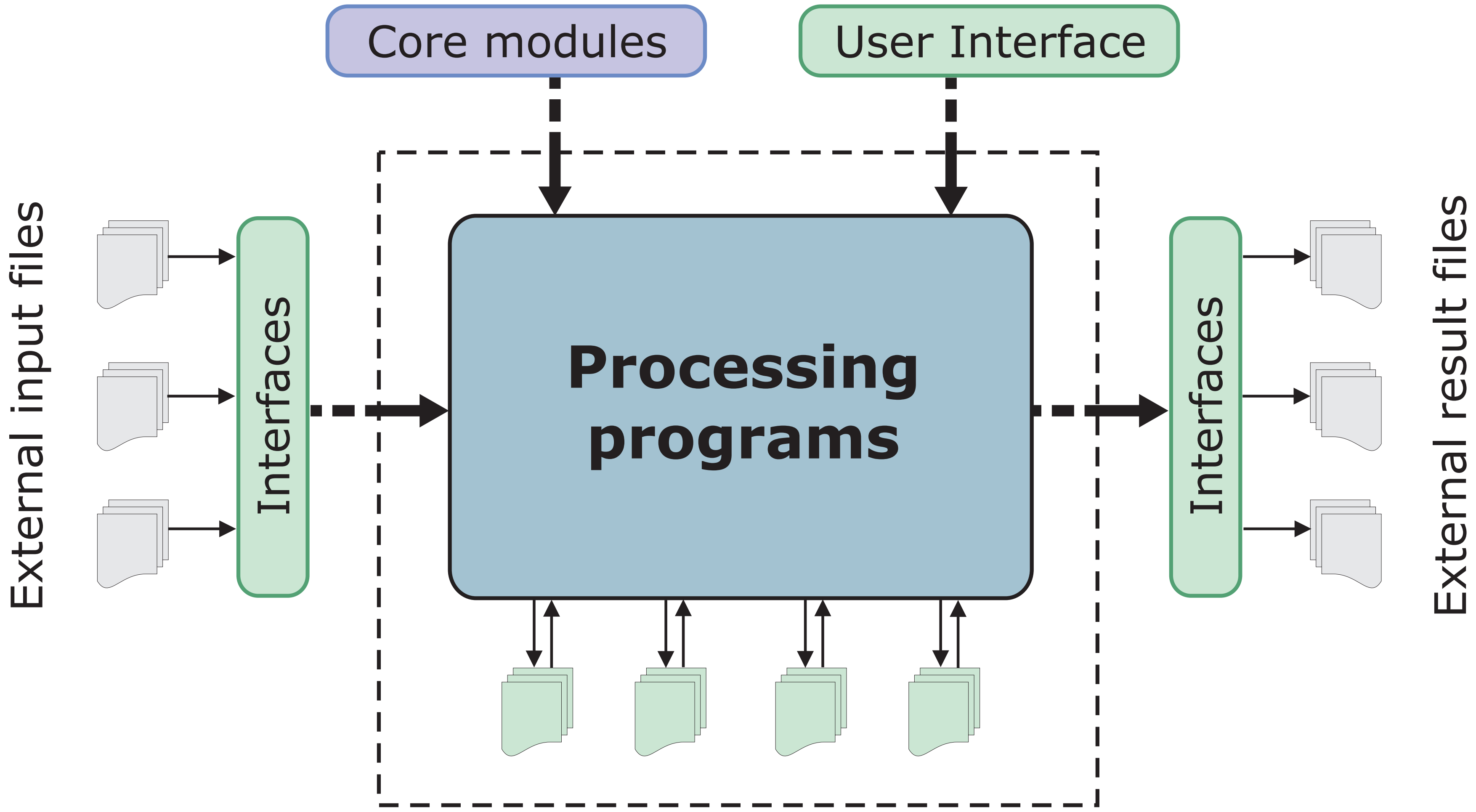

Example: Bernese GNSS Software

Flexible handling of observation types is necessary:

- A complex set of modern F90 modules guarantees a flexible access to the measurements with individual linear combinations for each GNSS.
- The use of these modules simplifies the observation handling within the processing programs.
- New linear combinations may be easily implemented at one place for the entire software package.
- Consequences for several internal files for observations, residuals, DCBs, GNSS–specific PCV corrections, . . .
- Consequences for external files formats: RINEX, ANTEX, SINEX, SP3c, . . .

⇒ M. Meindl et al., Developing a Generic Multi–GNSS Software Package, IGS Workshop, Miami, June 2008.

GNSS: Developments and Benefit

- More observation types, more GNSS:
  The world of GNSS will become more colors —
  the future seems to become much more complicate.

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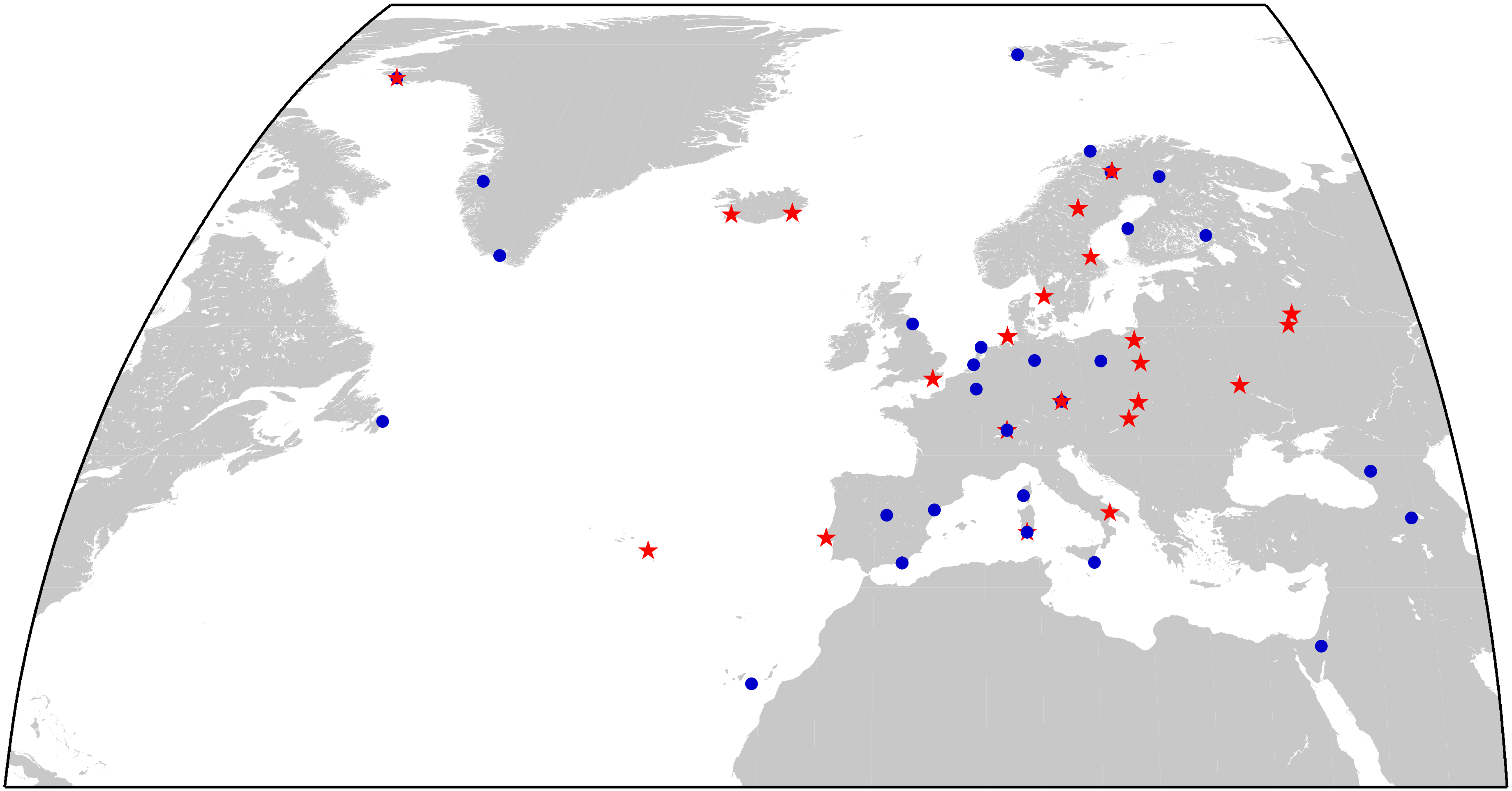
Do we benefit from additional GNSS satelites?

- Test case:
  combination of GPS and GLONASS observations for a kinematic positioning

Performance of a Kinematic Positioning

CODE EPN network



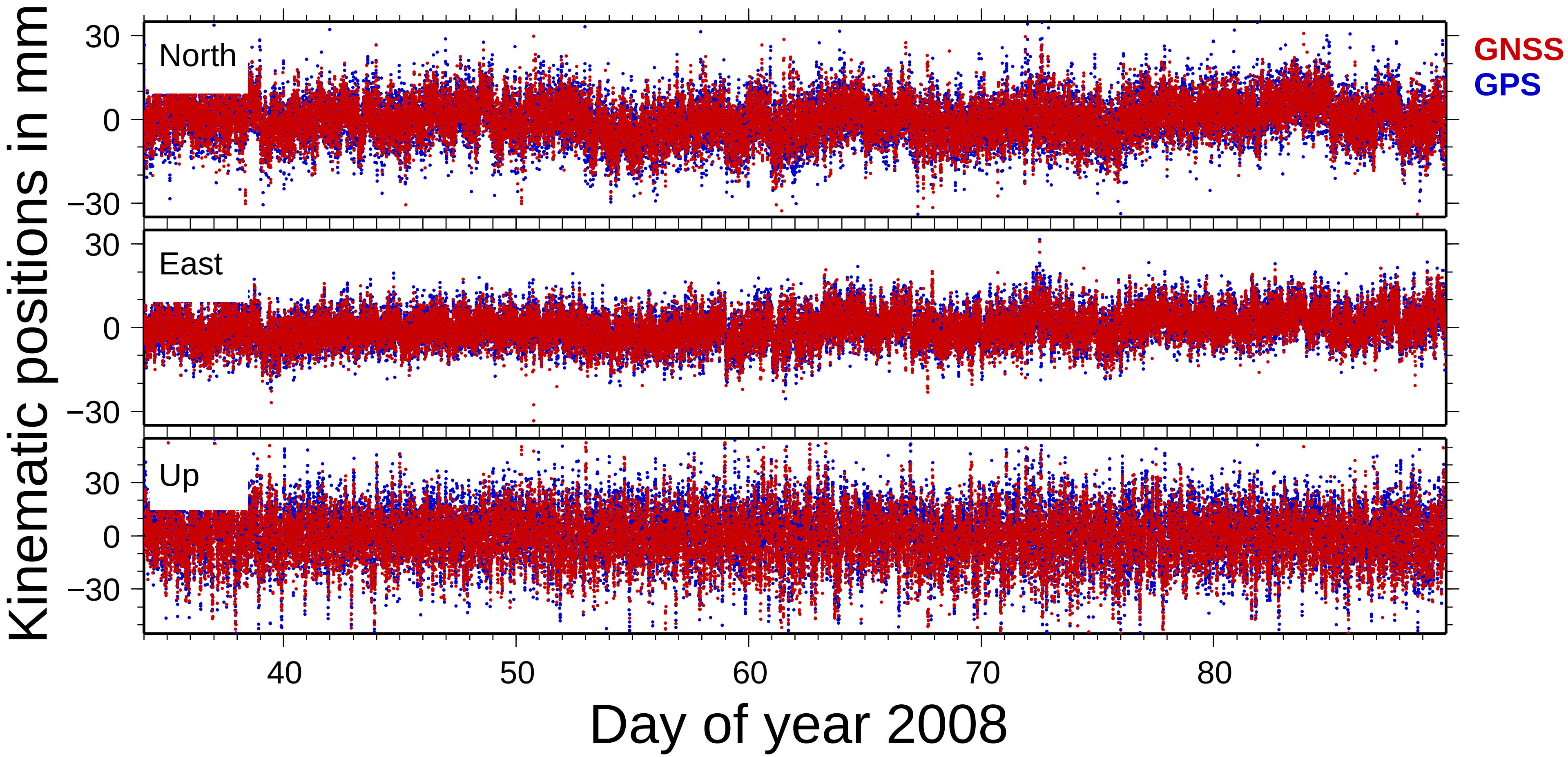
Receivers tracking: ★ GPS/GLONASS (24) ● only GPS (29)

CODE EPN solution for day of year 2007:034 to 089

Performance of a Kinematic Positioning

Results from a kinematic positioning

Example: station Zimmerwald (ZIM2)



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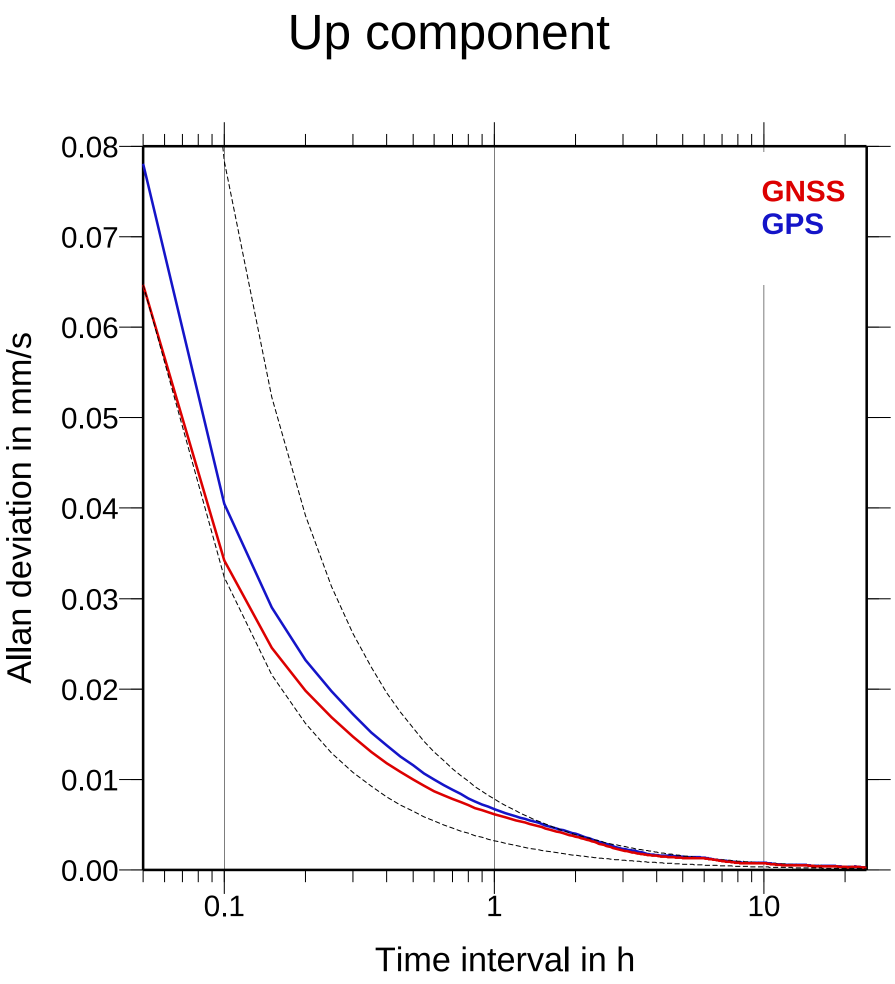
Performance of a Kinematic Positioning

Allan deviation from a kinematic positioning

Example: station Zimmerwald (ZIM2)

- The Allan deviation reflects the noise behavior of a time series.
- It is comparable with the RMS of epoch differences.
- The time interval gives the length between these epochs.



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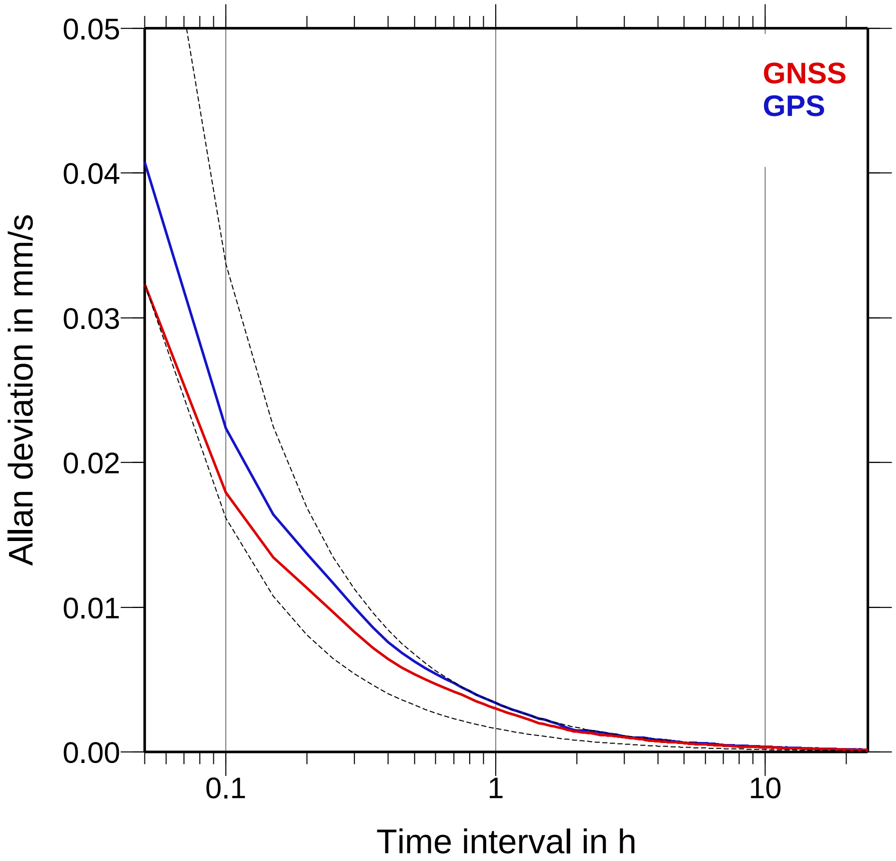
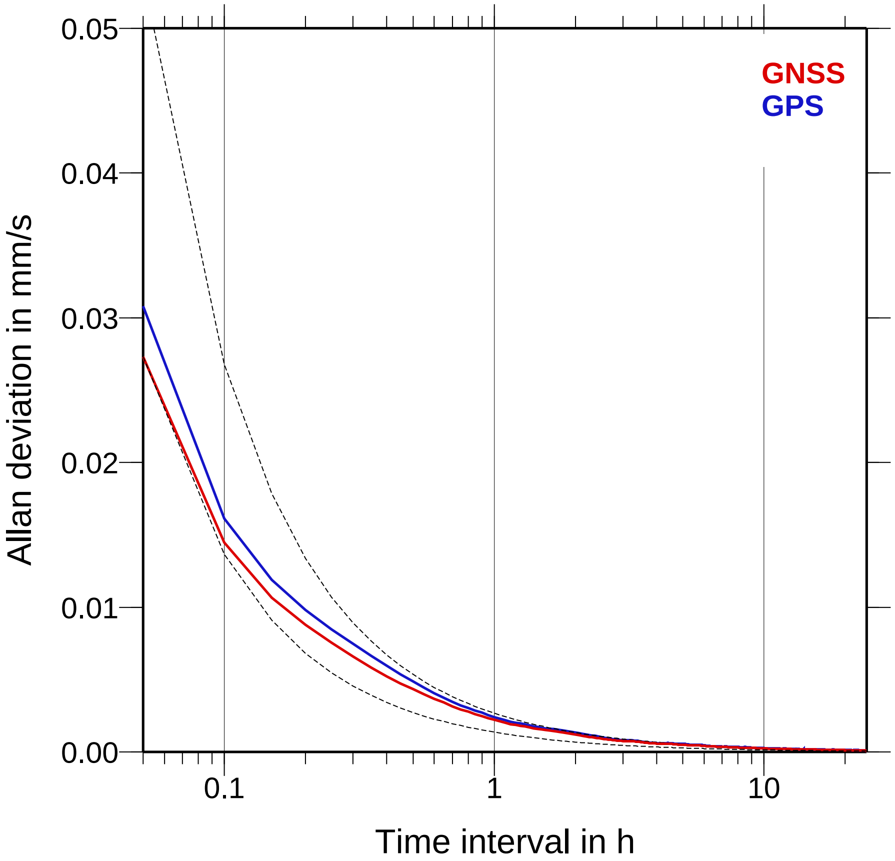


East component



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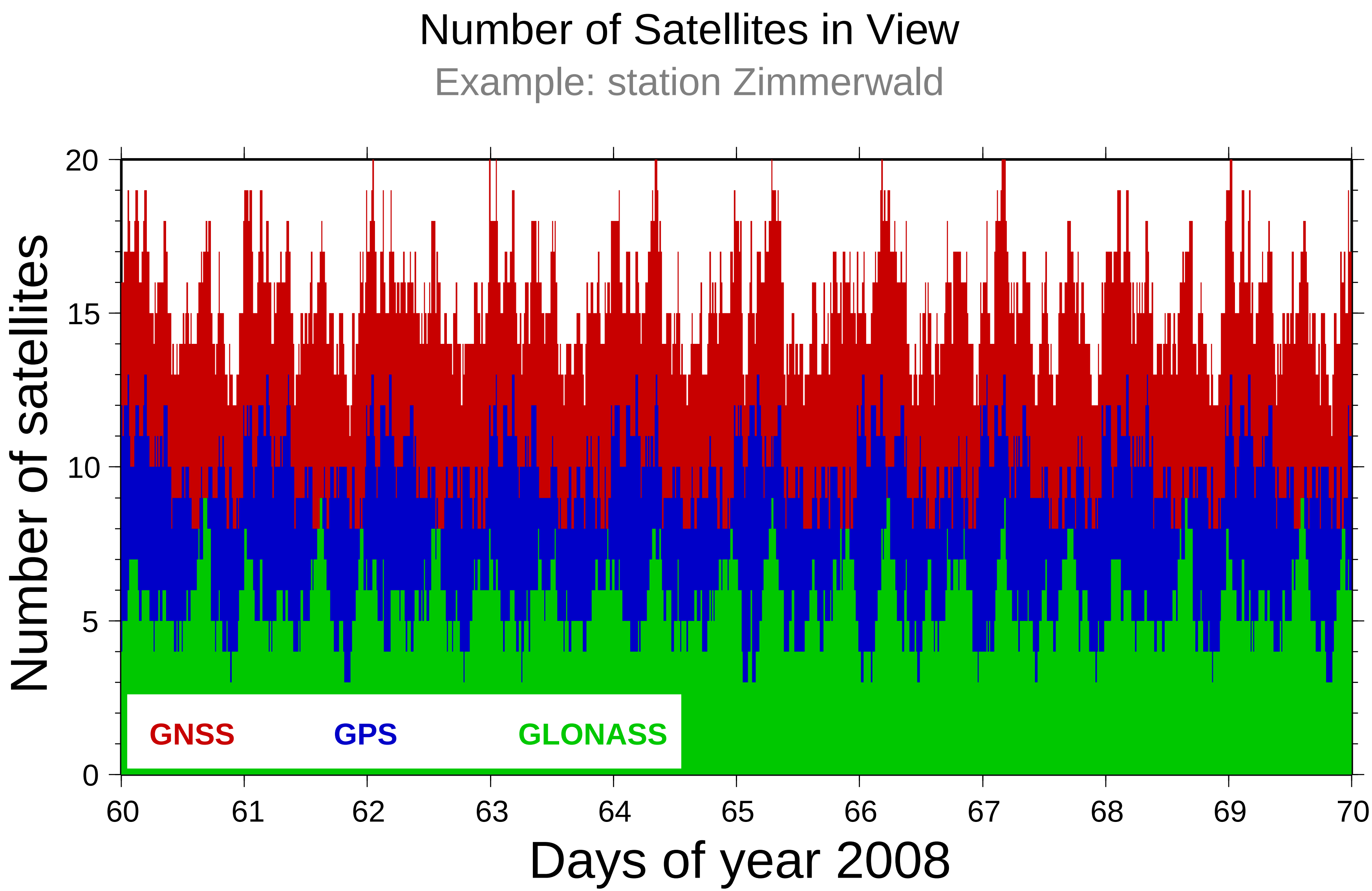
PDOP: Constellation Effects

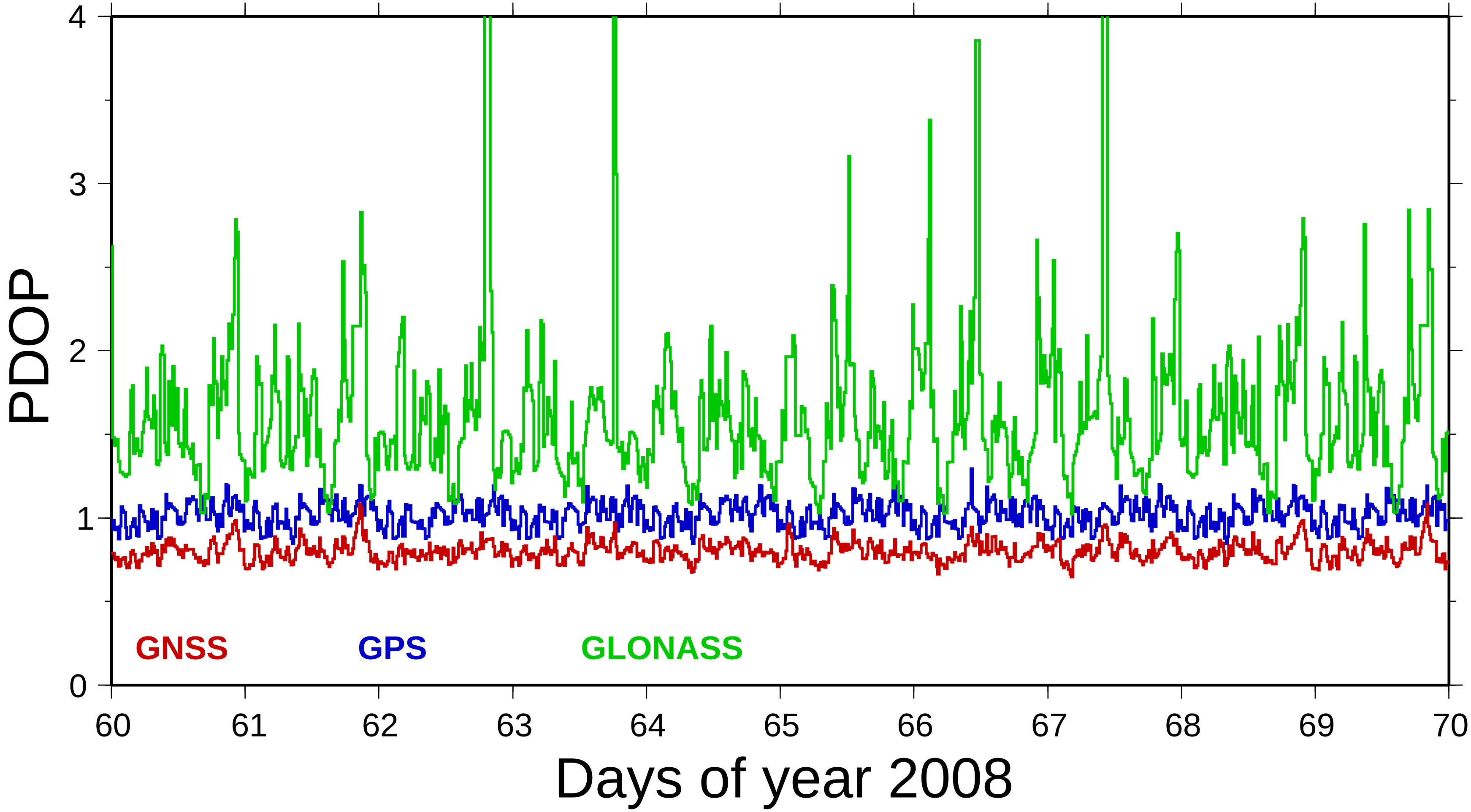


elevation cut–off 5°, day of year 2008:060 to 069

PDOP: Constellation Effects

PDOP values for satellite constellation in view

Example: station Zimmerwald



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PDOP: Constellation Effects

Spectra of PDOP values for satellite constellations

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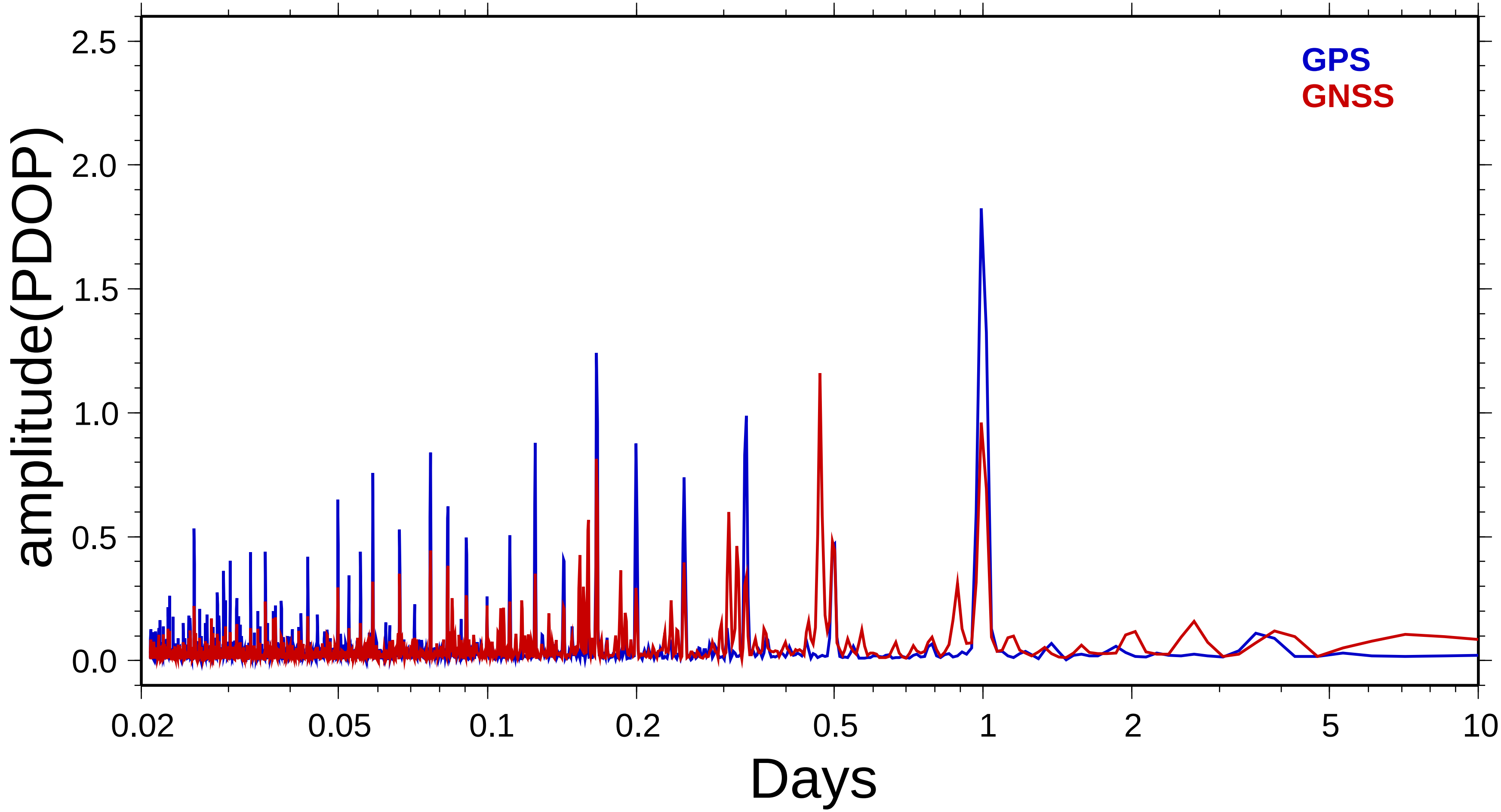

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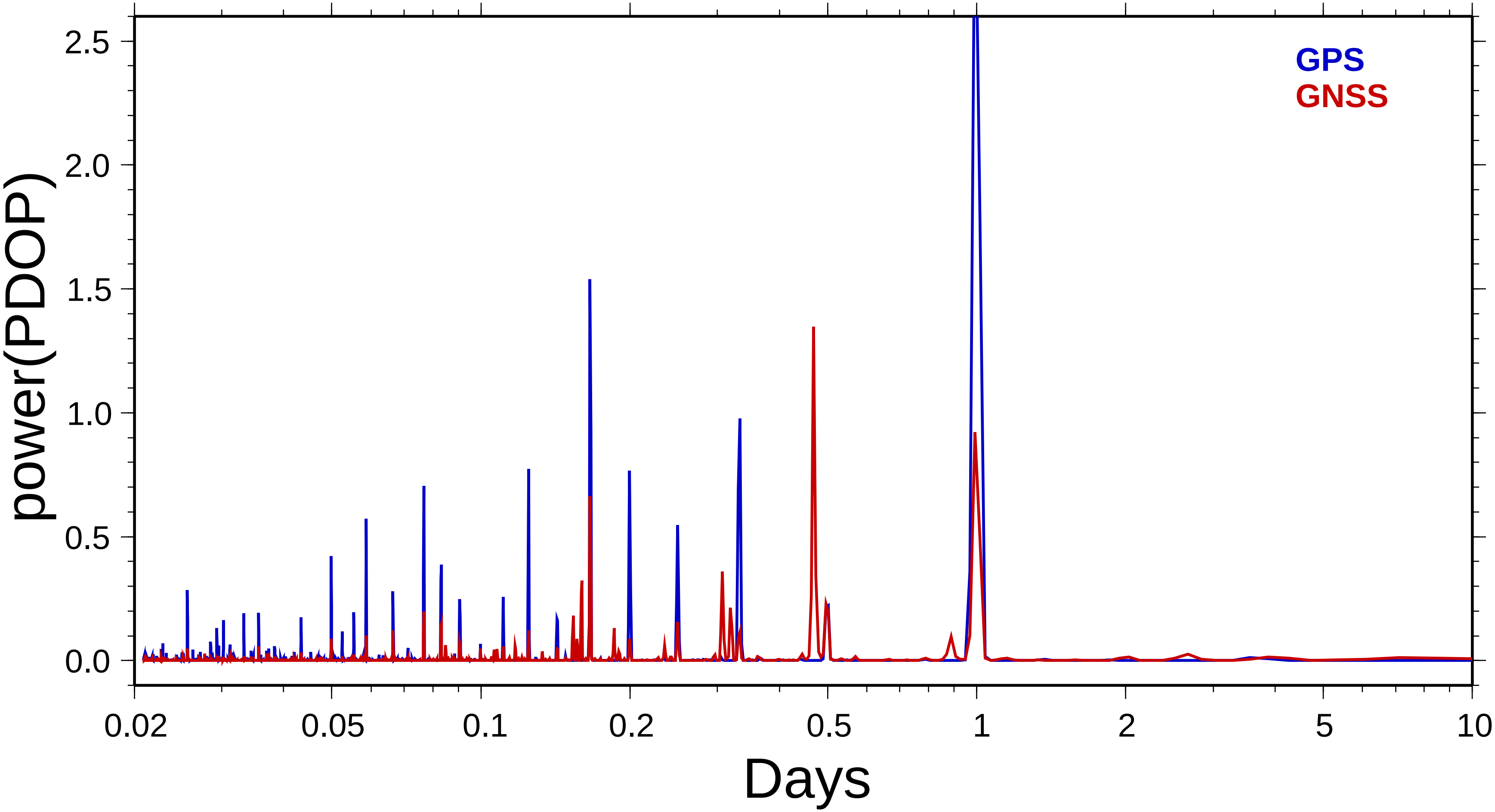

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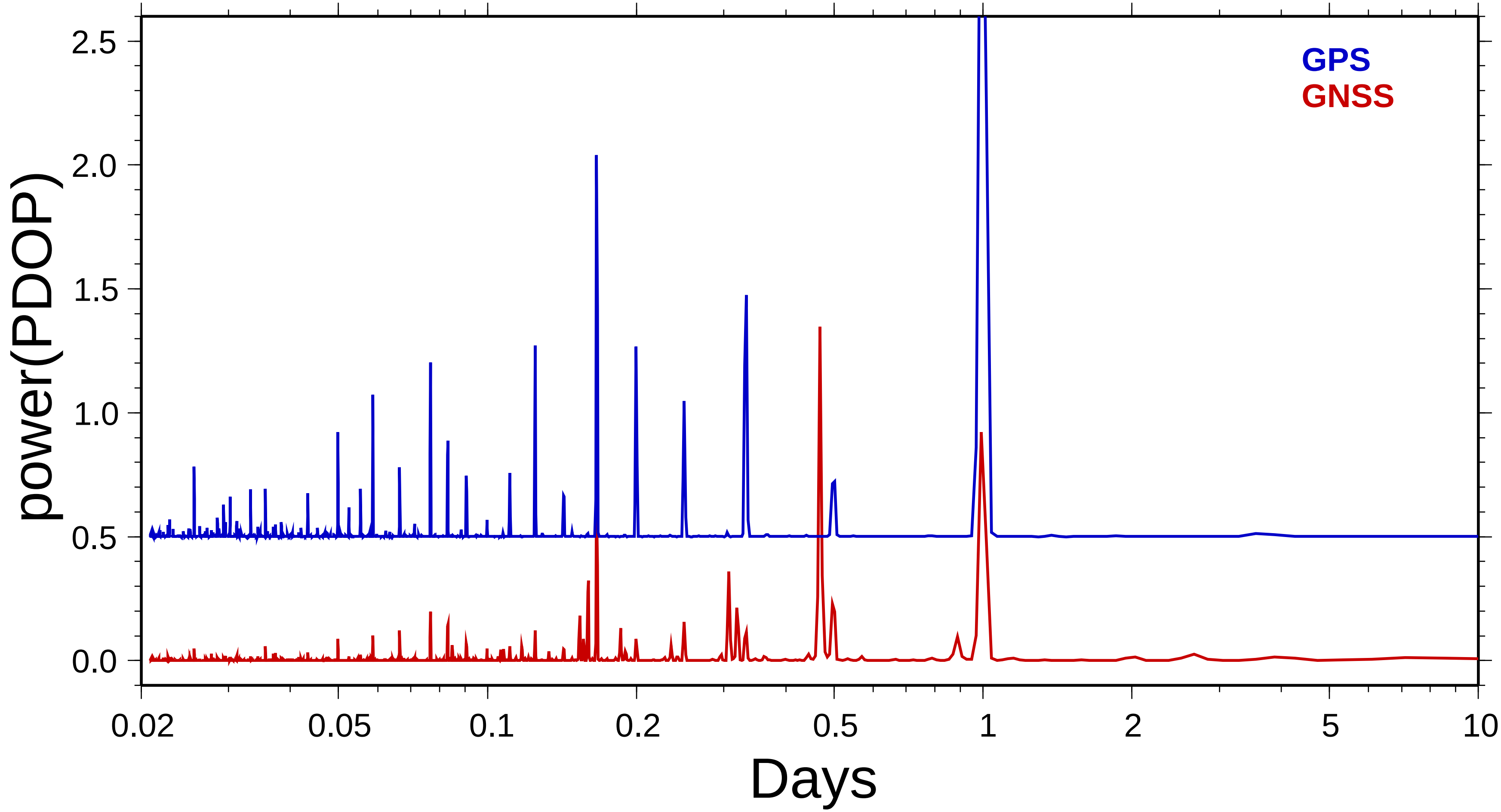

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AIUB: One of the GGSP–Partners

GGSP: Galileo Geodetic Service Provider Prototype

- Purpose: Generation and Maintenance of the geodetic basement for Galileo coordinates of GESS/GSS in the GTRF as a special realization of the ITRF
- „Mini–IGS“ of the European analysis centers:

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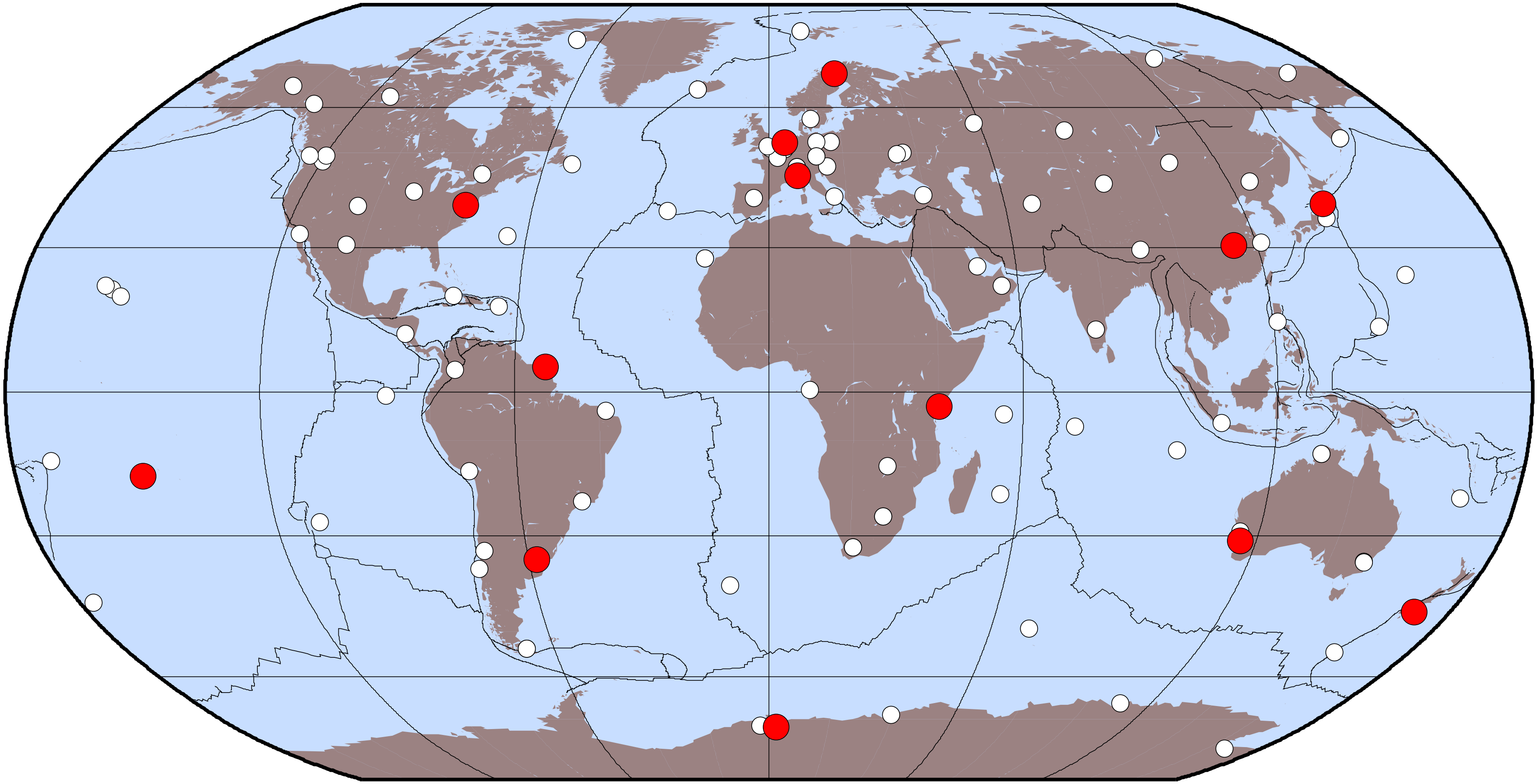
Network of GTRF–stations



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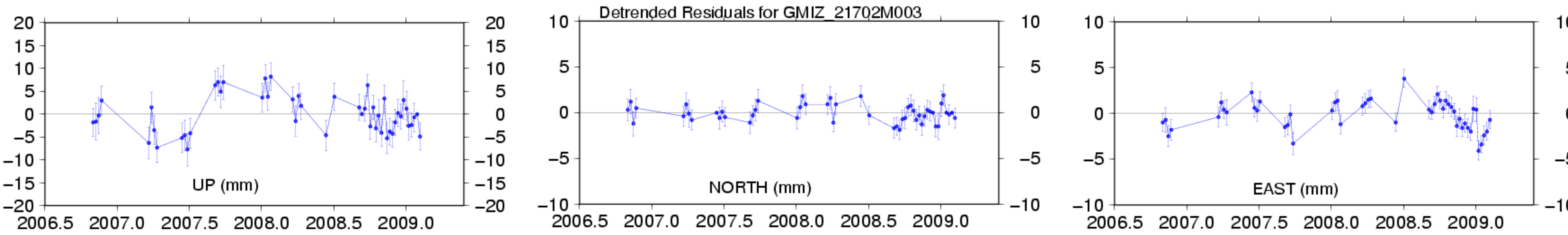
List of products provided by the GGSP:
corresponds to the IGS final products series

- GTRF: coordinates and velocities of the GESS/GSS
- high precision GNSS satellite orbits
- Earth rotation parameters
- satellite and receiver clock corrections



Söhne, Dach, Springer, Gendt, Altamimi, and GGSP Prototype Team: Galileo Terrestrial Reference Frame and beyond: the GGSP project. EGU, Vienna, 2009.

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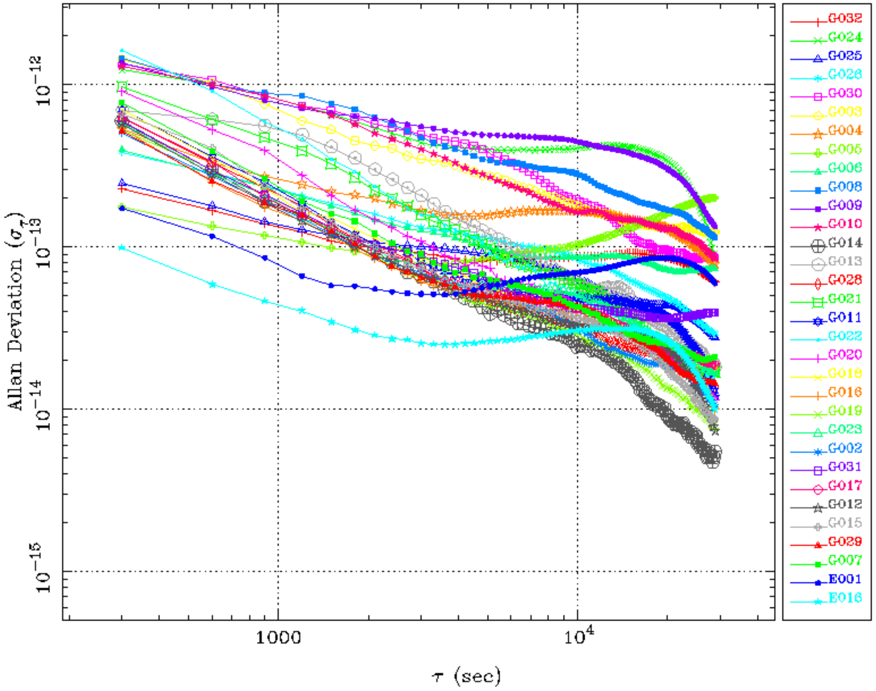
Within the GGSP also GIOVE data have been processed.
Performance of the GIOVE satellite clocks



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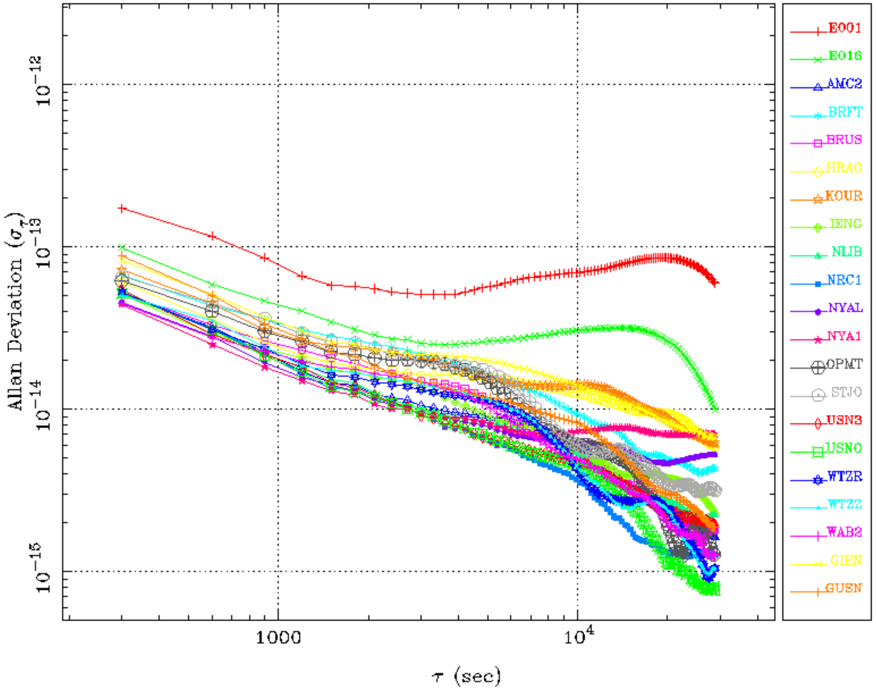

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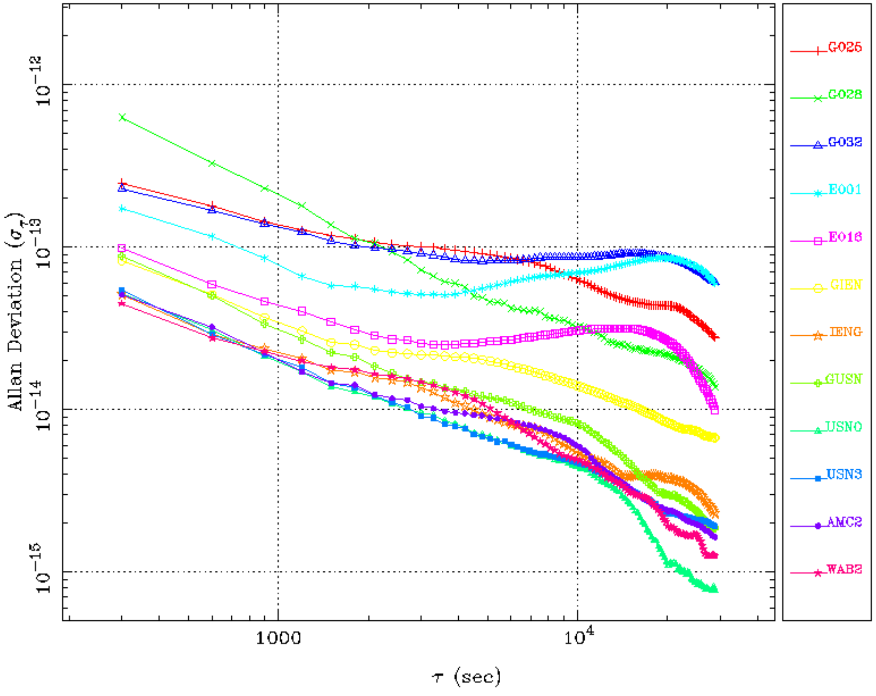

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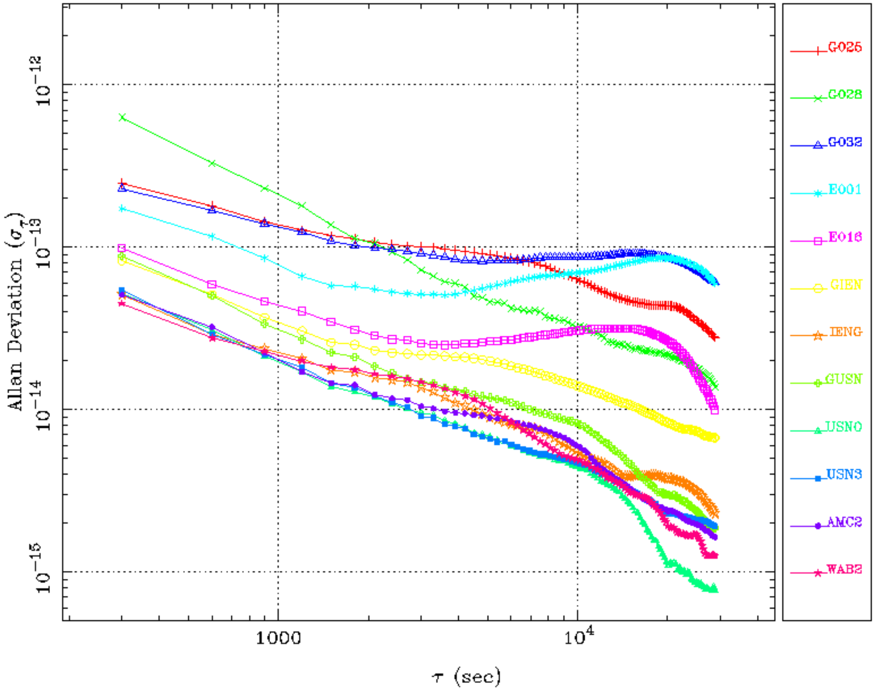

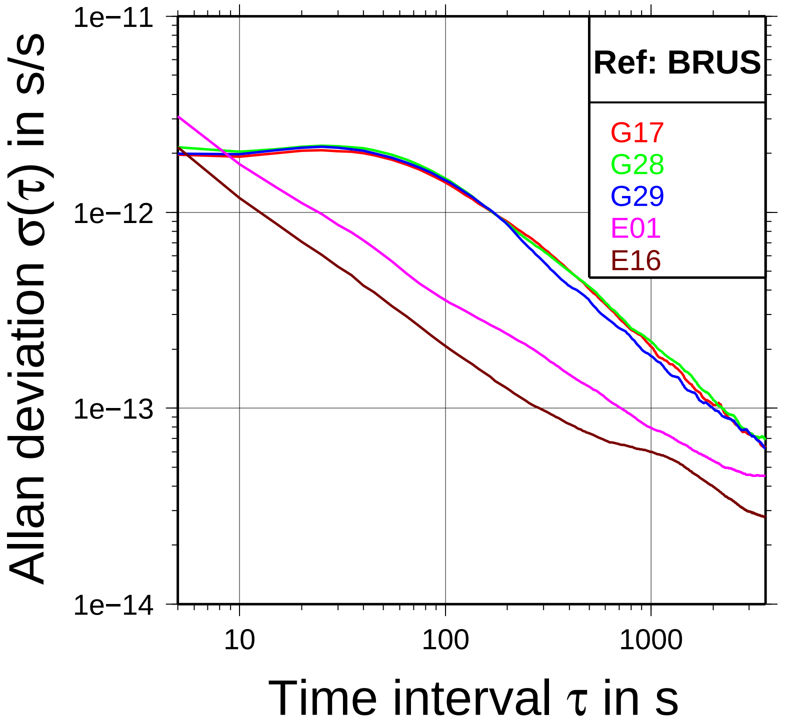

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Summary

- Today we have two dual–frequency GNSS in operation.

- In future the GNSS picture will be more colorful:
  - modernization of the existing GNSS and new GNSS
  - a big variability of observation types (between but even within the GNSS)

Summary

- Today we have two dual–frequency GNSS in operation.
- In future the GNSS picture will be more colorful:
  - modernization of the existing GNSS and new GNSS
  - a big variability of observation types (between but even within the GNSS)
- In particular the kinematic positioning will benefit from additional satellites.
- Systematic effects will be reduced by GNSS satellites in different constellations.
- The GNSS components will benefit from the competition between the systems.

THANK YOU!