# Rigorously Combined Multi–System GNSS Analysis

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# Outline

## Rigorously Combined Multi–System GNSS Analysis:

1. Description of the multi–system analysis
2. Comparison of the satellite clock performance of the individual GNSS
3. Receiver antenna models for GNSS
4. Frequency dependent receiver code biases for GLONASS
5. Summary and Outlook

# Multi–System GNSS Analysis

General situation with multiple independent GNSS:

| | GPS | GLONASS |
|---|---|---|
| Orbits refer to | WGS–84 | PZ–90 |
| Satellite clocks refer to | UTC(USNO) | UTC(SU) |
| Signal propagation | dual–frequency microwave systems | |
| Multipath | individual for each GNSS (mainly freq. dependent) | |
| constellation repeatability | one sidereal day | one sidereal day |
| ground track repeatability | one sidereal day | eight sidereal days |
| Station coordinates refer to | WGS–84 | PZ–90 |
| Station clocks refer to | UTC(USNO) | UTC(SU) |

# Multi–System GNSS Analysis

The observations from all GNSSs are analysed together in one parameter estimation process to get the best possible consistency for all products.

| | GPS | GLONASS |
|---|---|---|
| Orbits refer to | IGS 00b | |
| Satellite clocks refer to | one common reference clock, or IGST | |
| Signal propagation | dual–frequency microwave systems | |
| Multipath | individual for each GNSS (mainly freq. dependent) | |
| constellation repeatability | one sidereal day | one sidereal day |
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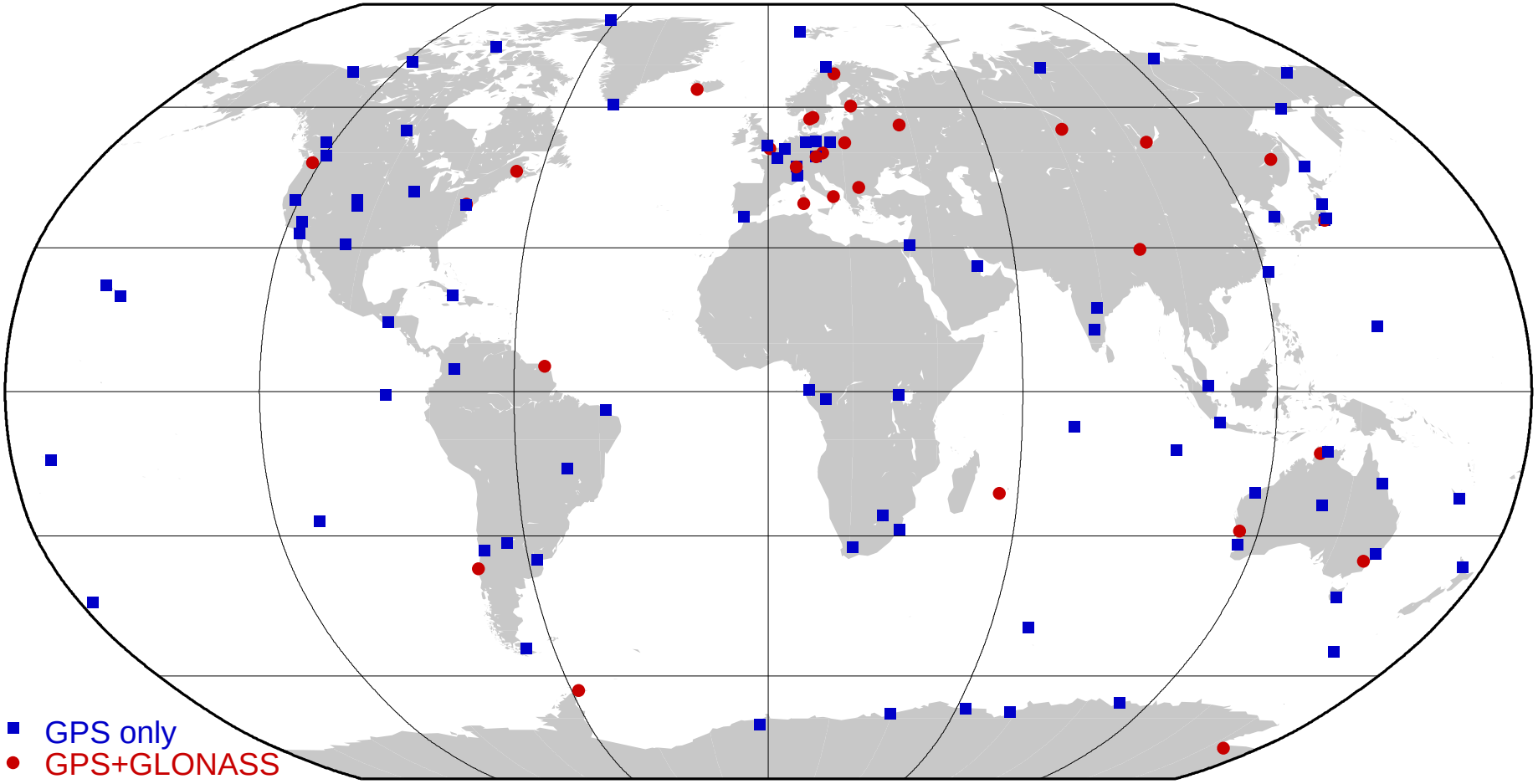
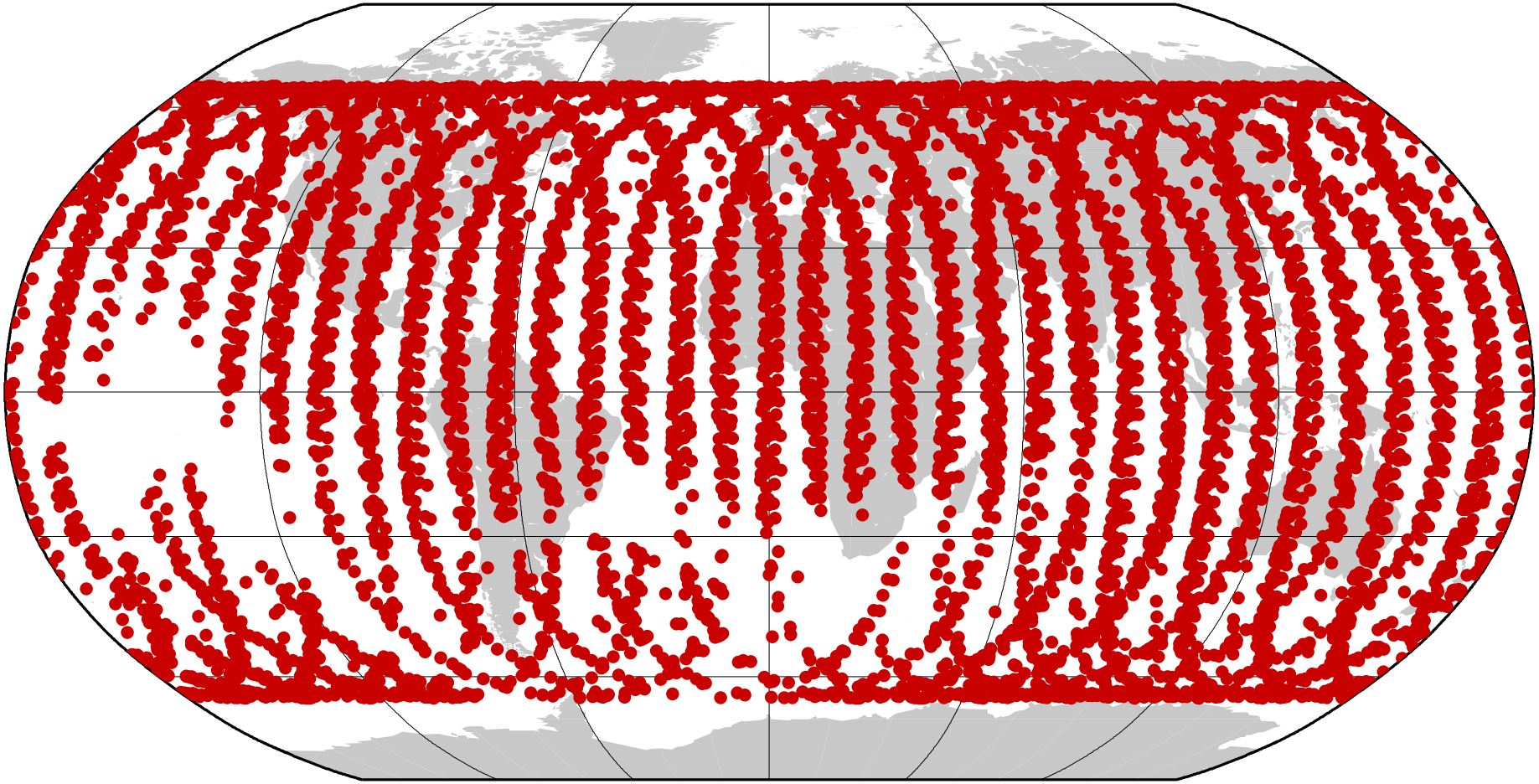
# Multi–System GNSS Analysis

## GNSS Station Distribution (used by CODE)

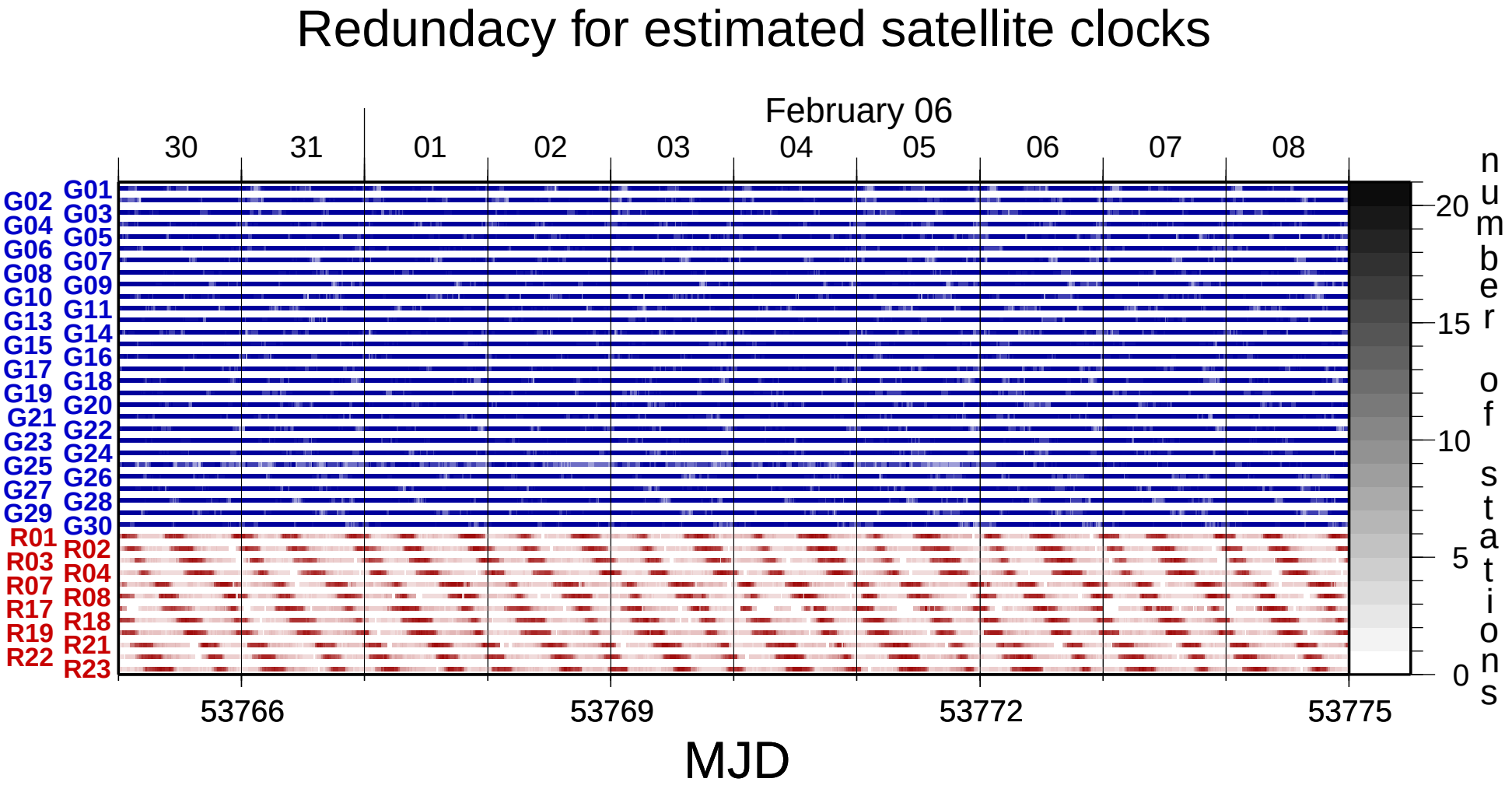


# Multi–System GNSS Analysis

Availability of GLONASS satellite clocks

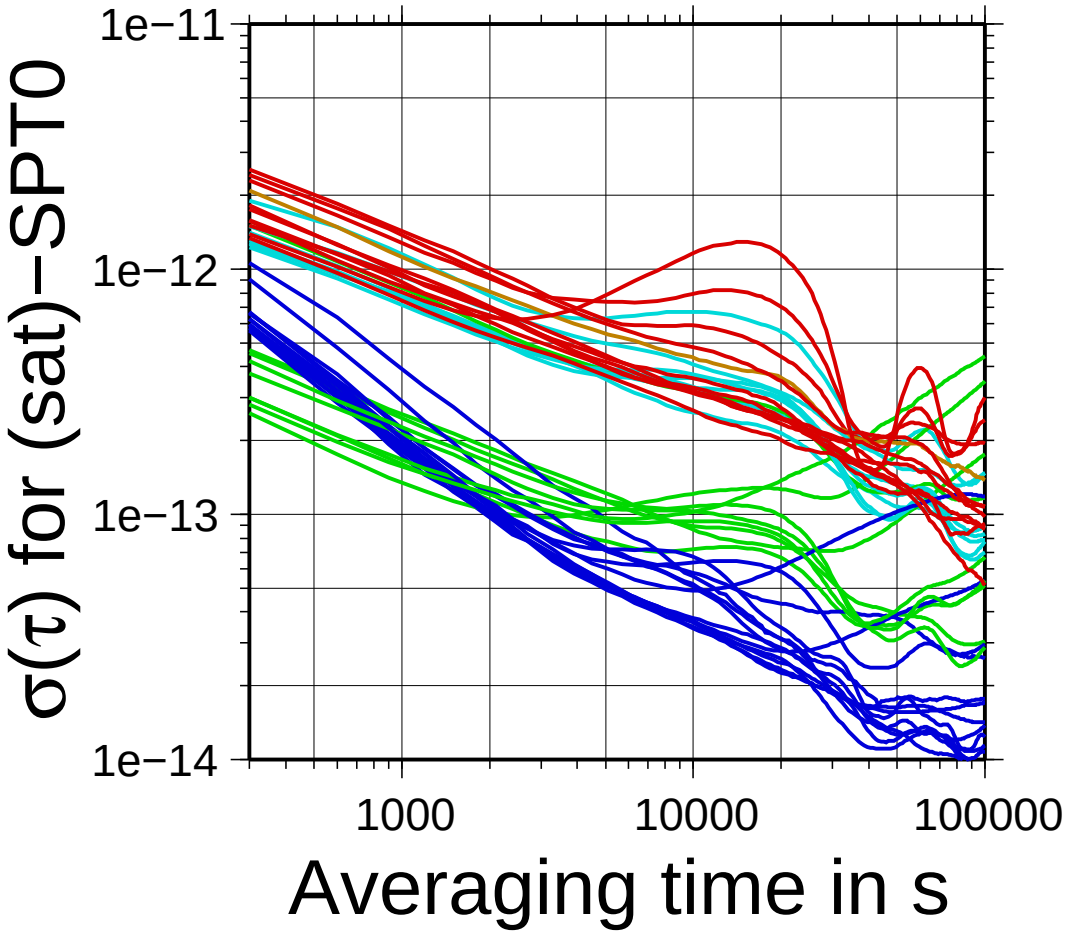


# Multi–System GNSS Analysis



# Multi–System GNSS Analysis

## Satellite clock performance




Legend:

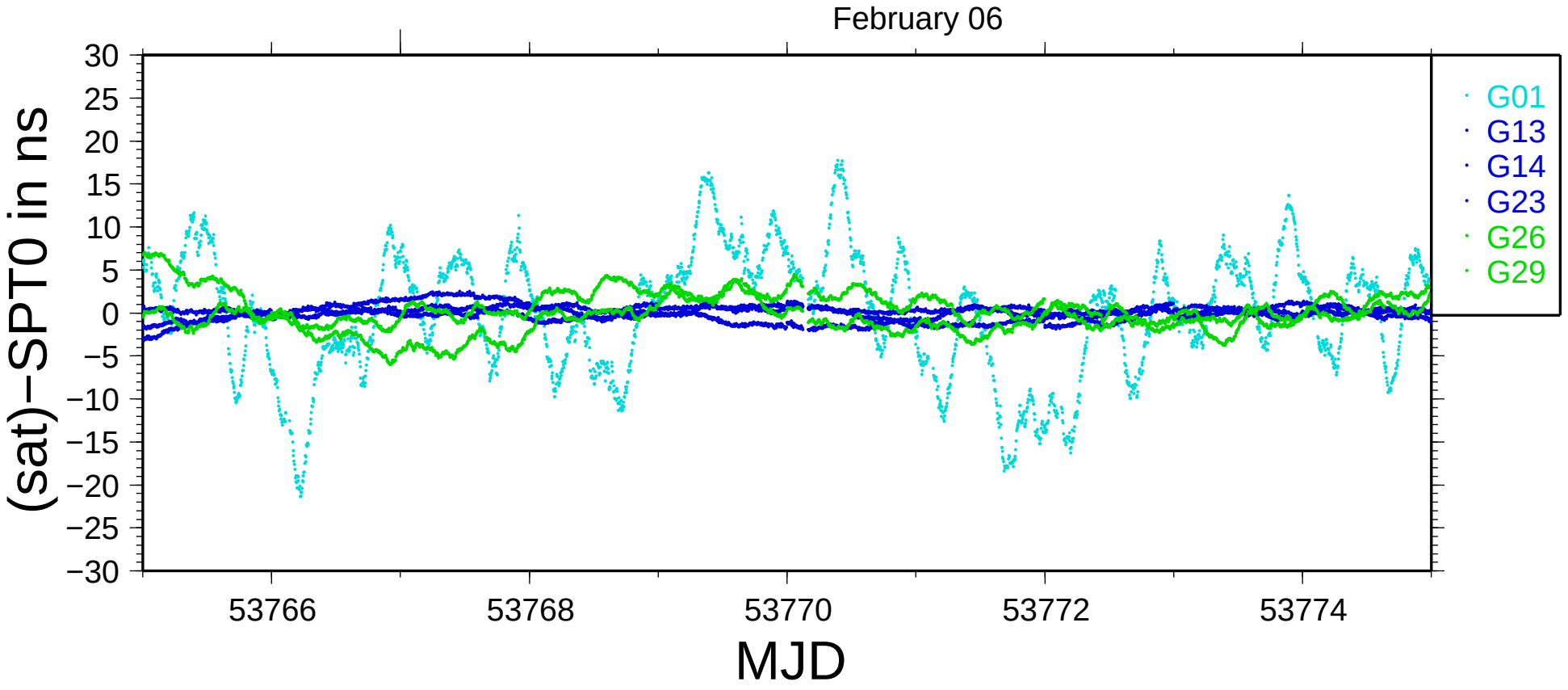
- GPS (Block II, IIA), Cs
- GPS (Block II, IIA), Rb
- GPS (Block IIR, IIF), all Rb
- GLONASS
- GLONASS–M

The same stations were used to estimate the GPS and GLONASS satellite clock corrections.

# Multi–System GNSS Analysis

## Satellite clock performance

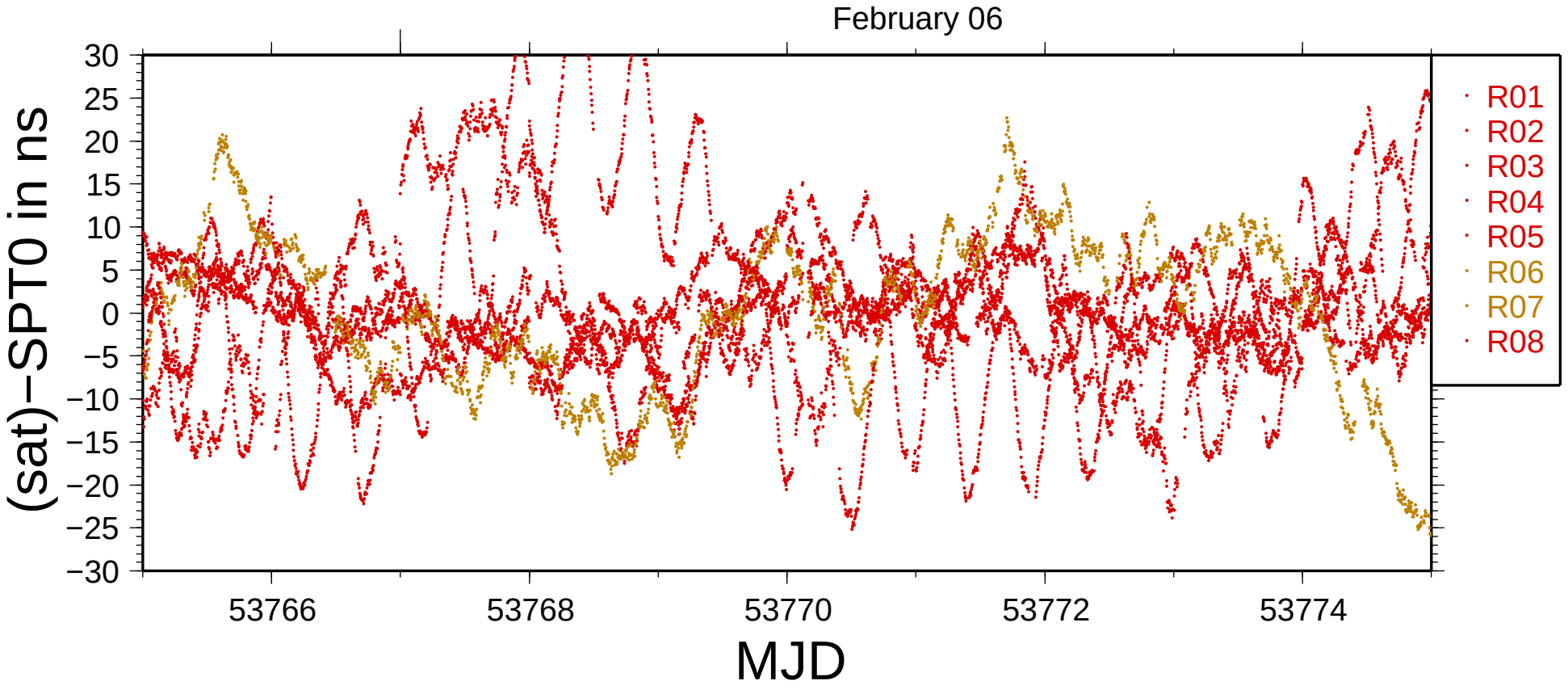
GPS satellites of plane *f*



# Multi–System GNSS Analysis

## Satellite clock performance

GLONASS satellites of plane *a*



# Receiver/Antenna Bias

If consistent products for multiple GNSS are available to the user community

- PPP solutions for single system receivers of different GNSS give comparable results and
- GNSS network solutions.

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- GNSS network solutions.

Nevertheless the biases of the users GNSS receiver/antenna remains in the data analysis:

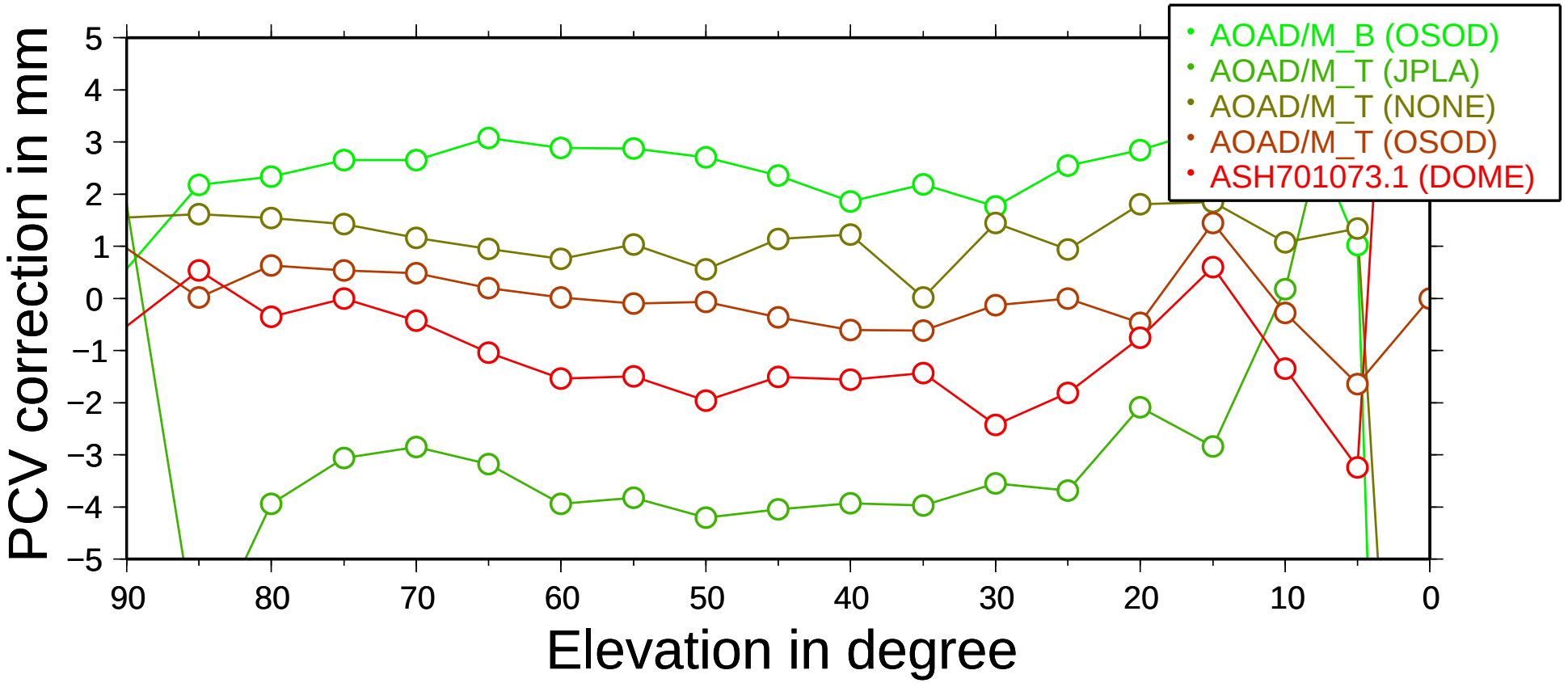
Receiving signals from different GNSS with one equipment let us expect biases because of different signal structure and different frequencies that are used:

- Receiver antenna model
- Receiver intersystem, interfrequency biases

# Receiver Antenna Bias

## Receiver antenna model

Estimated corrections for GLONASS observations wrt. the GPS derived model.



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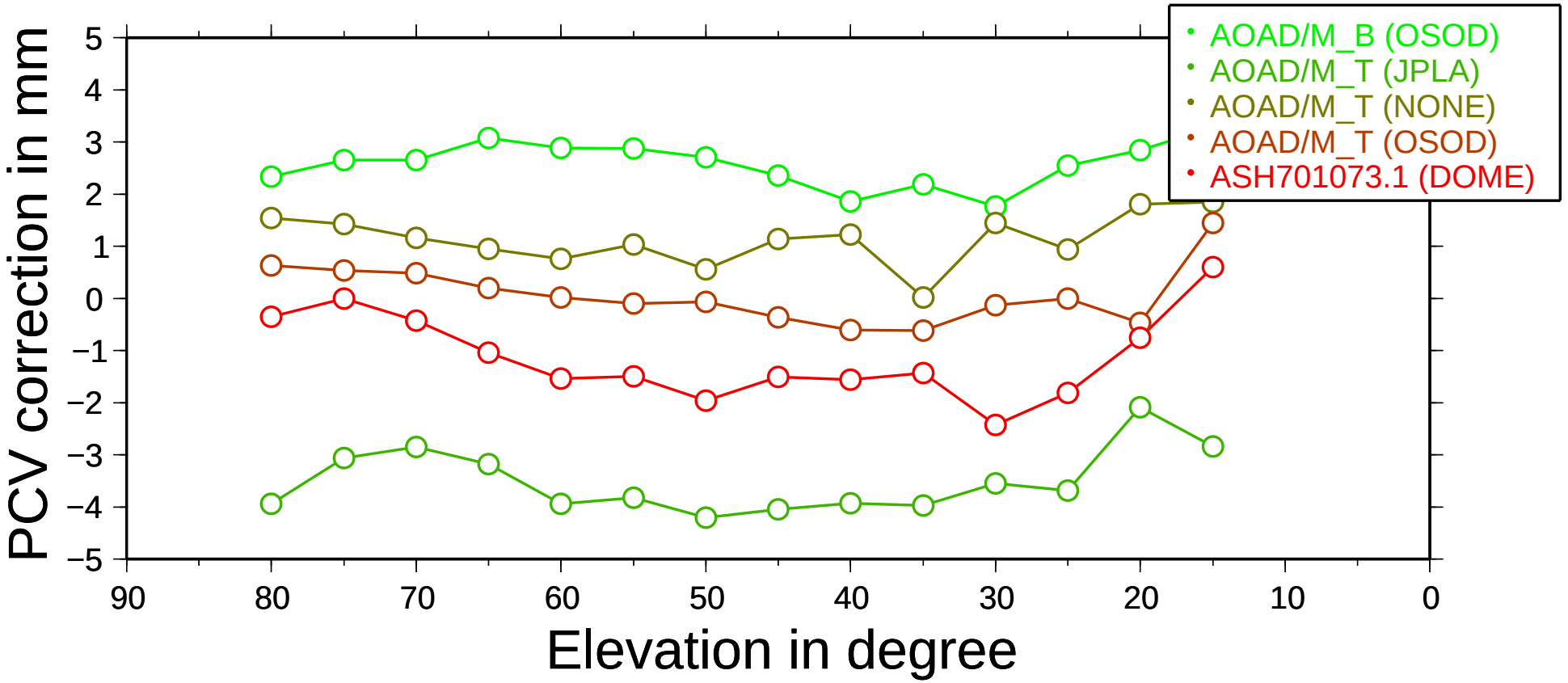

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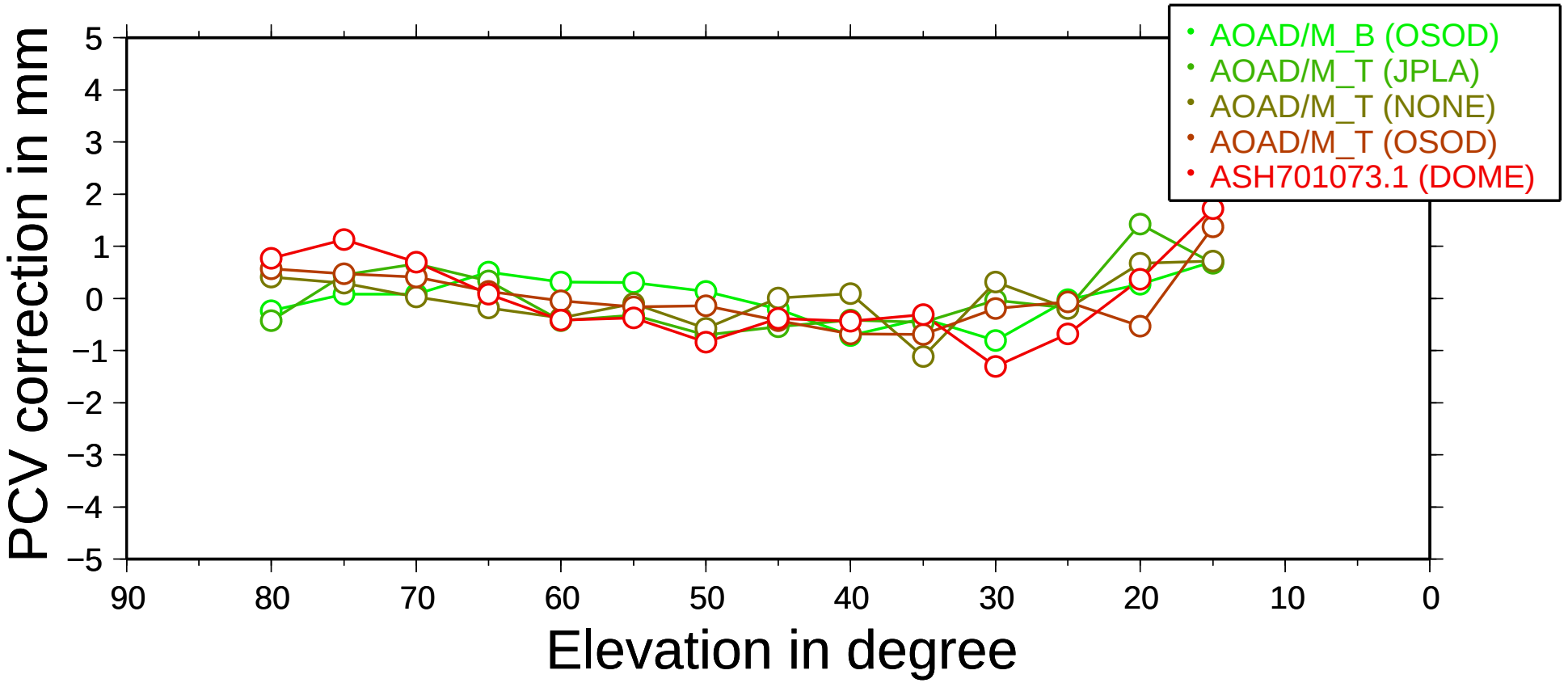
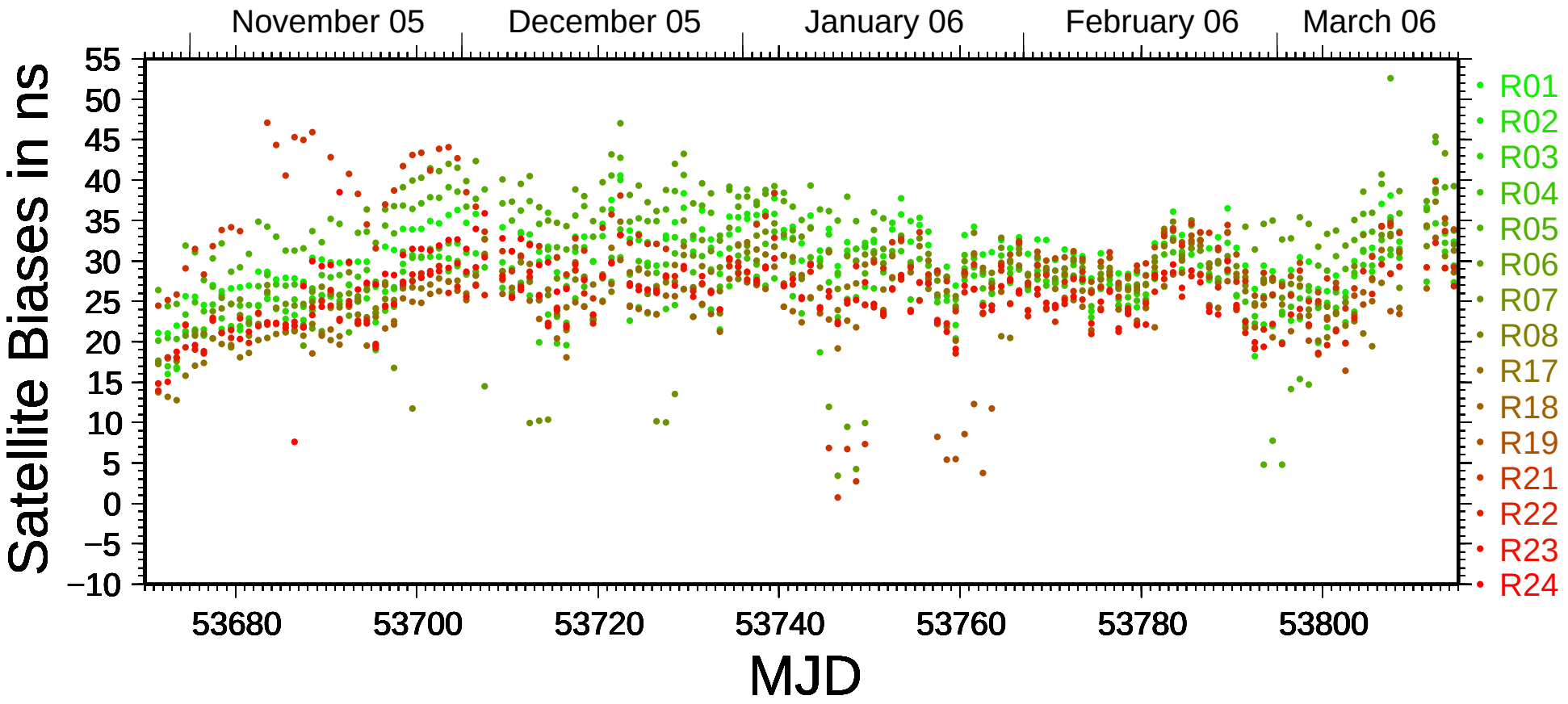


# Receiver Satellite Bias

## Receiver satellite biases for ONSA

only plotted for the GLONASS satellites



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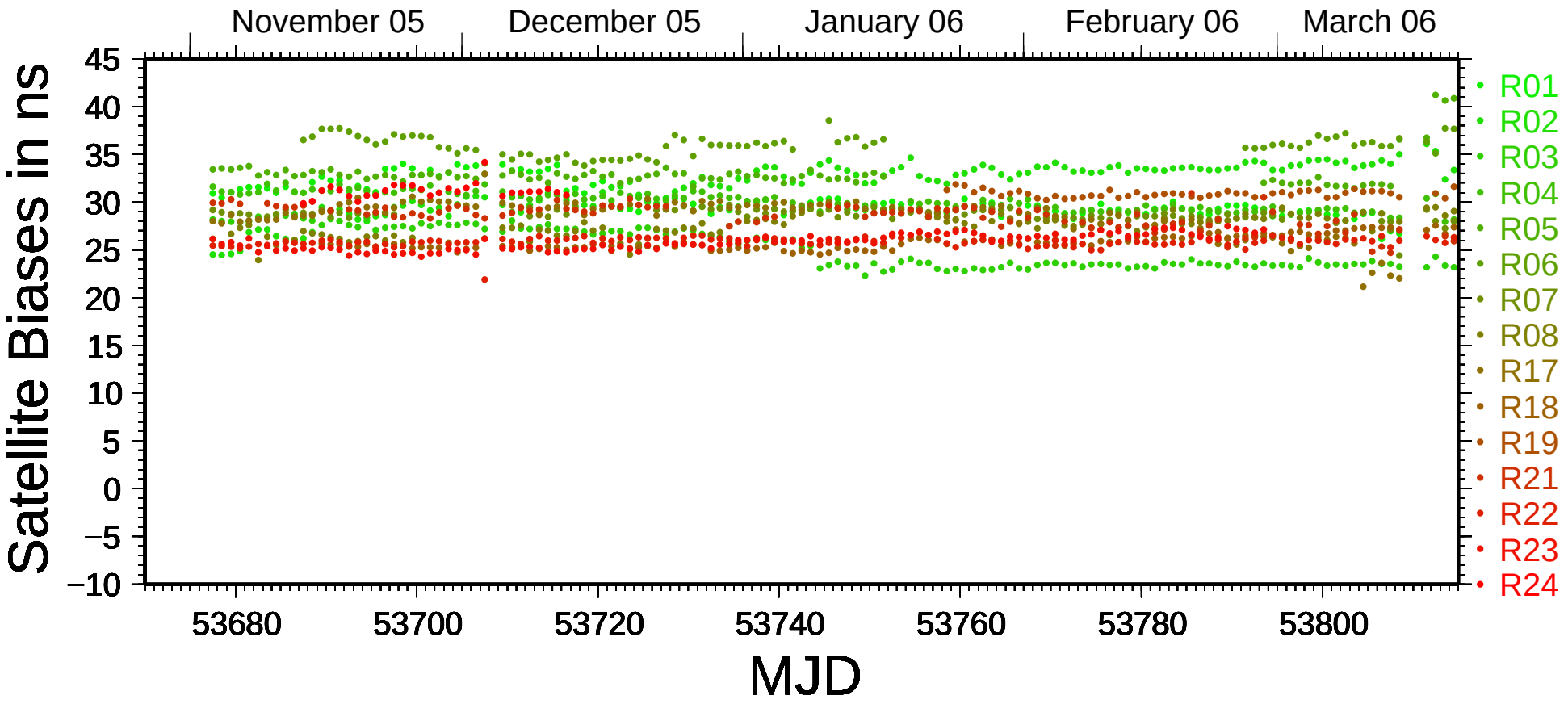

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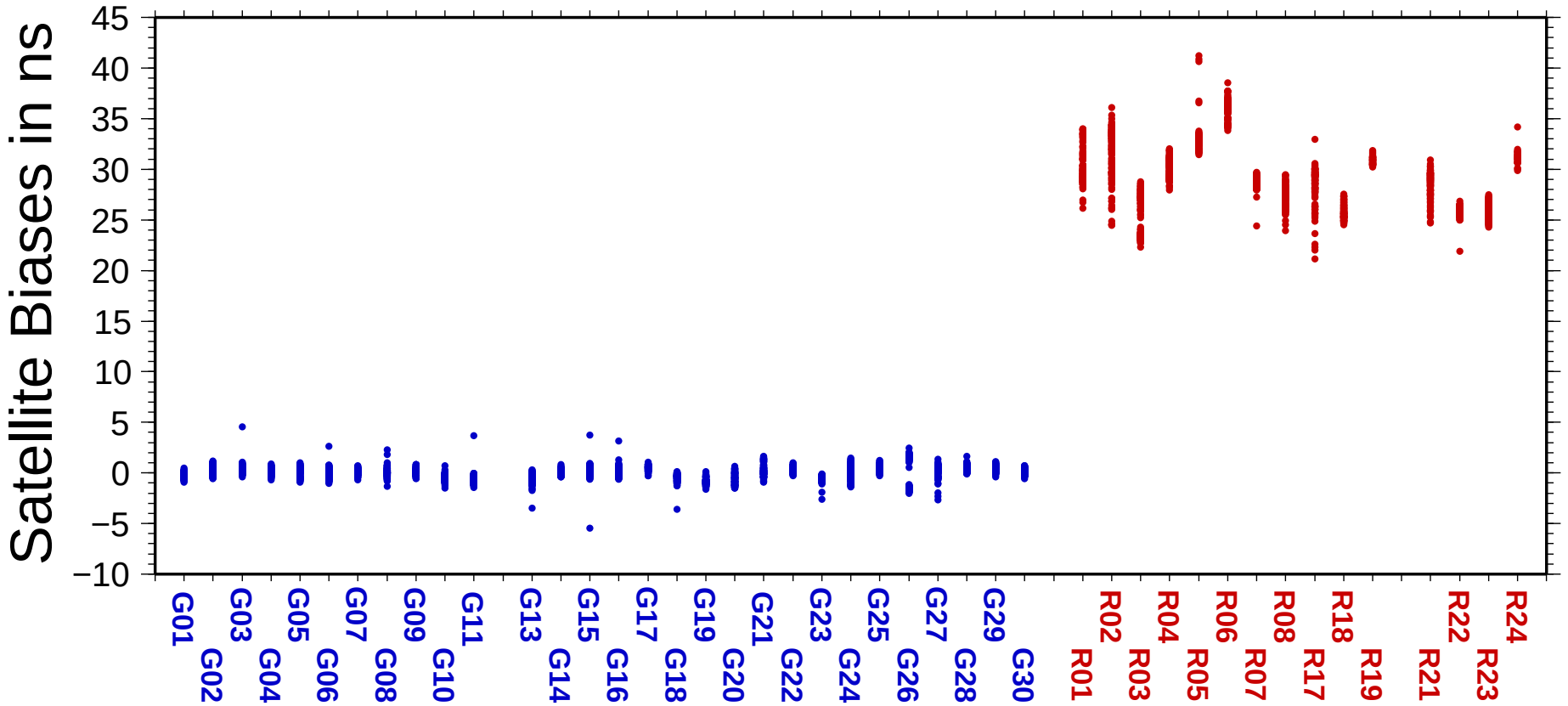

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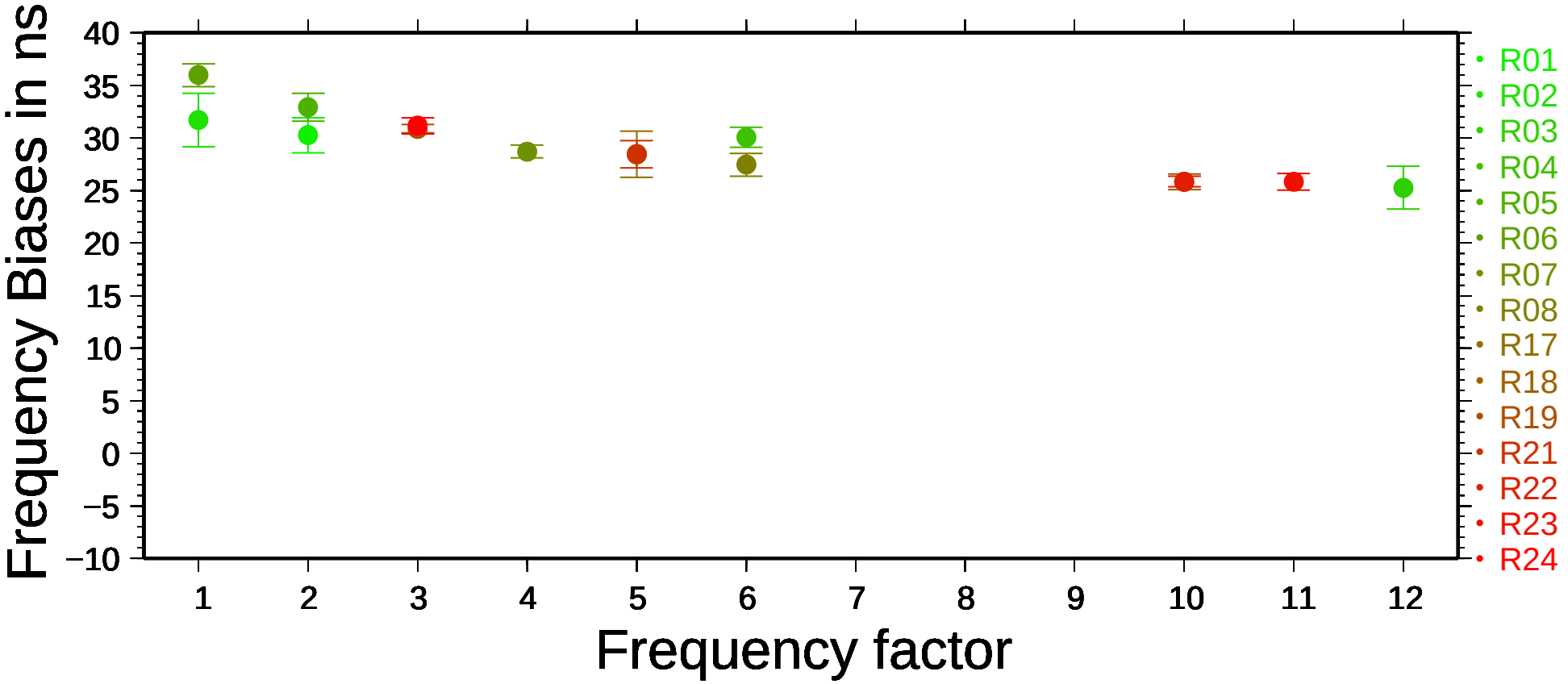
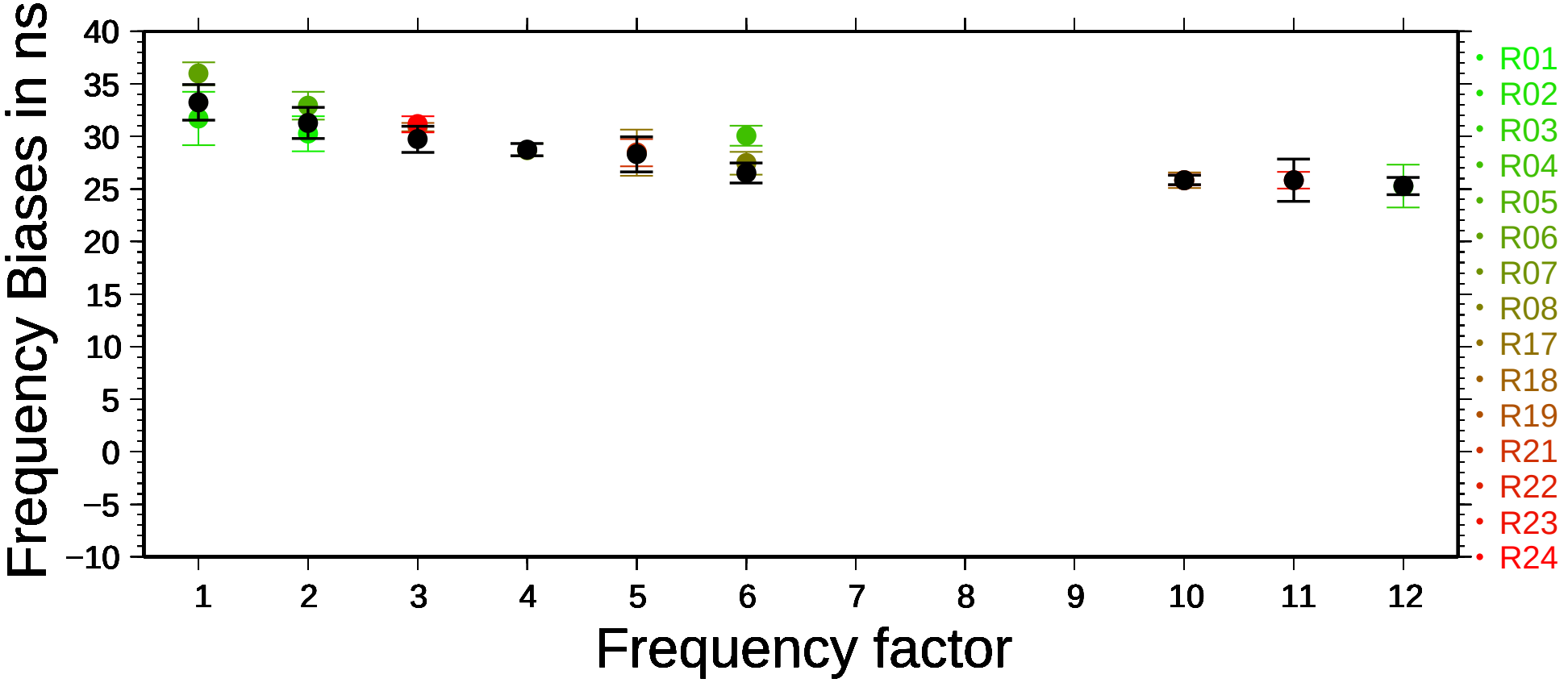


# Receiver Satellite Bias

## Receiver interfrequency biases for ONSA

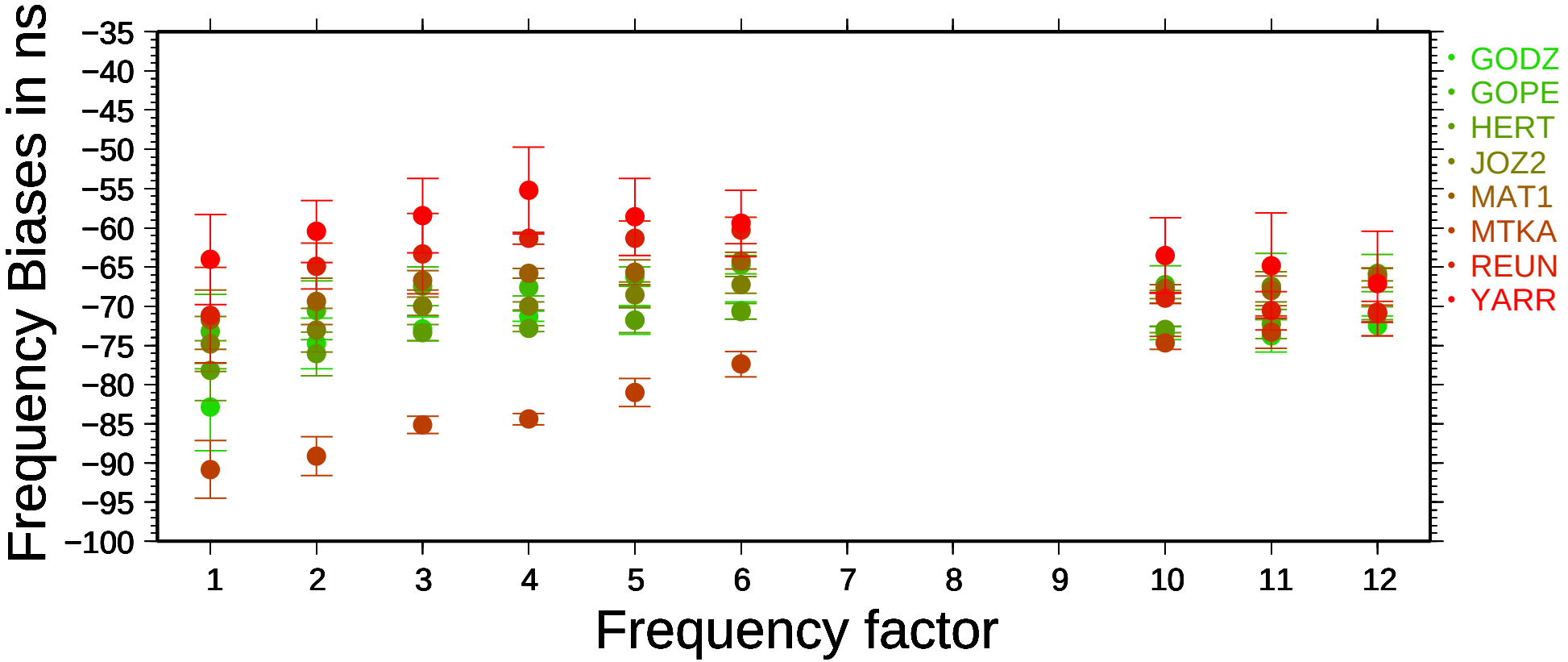
Relative to the GPS frequencies



# Receiver Frequency Bias

## Receiver interfrequency biases for ASHTECH Z18

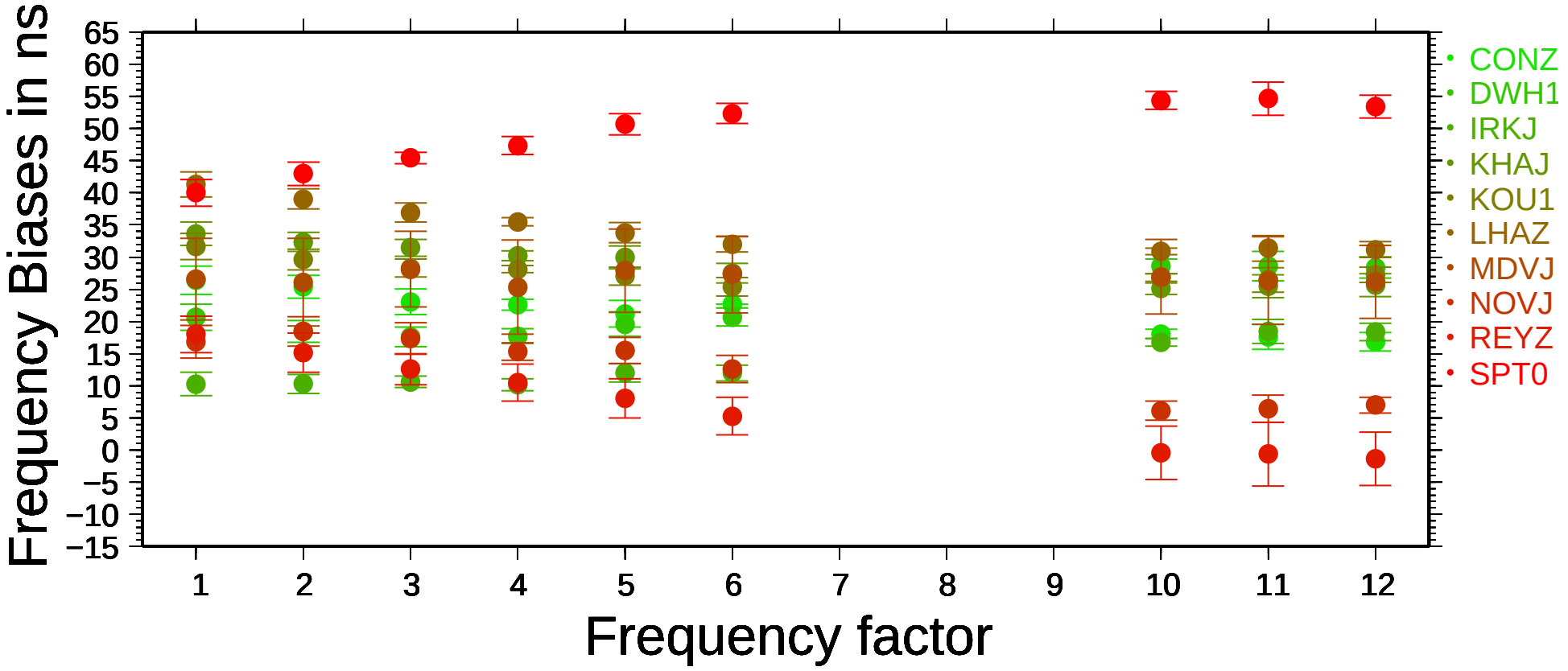
Relative to the GPS frequencies



# Receiver Frequency Bias

## Receiver interfrequency biases for JPS LEGACY

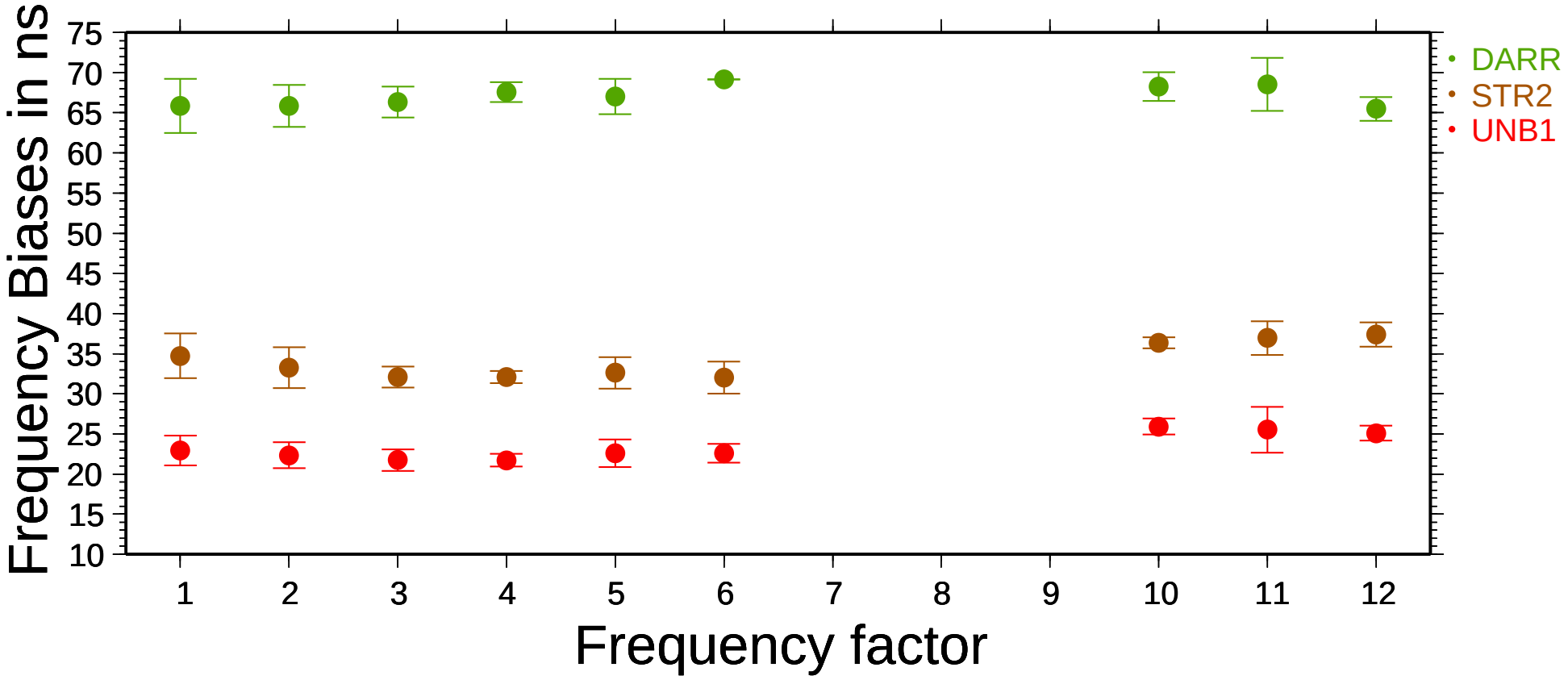
Relative to the GPS frequencies



# Receiver Frequency Bias

## Receiver interfrequency biases for TPS LEGACY

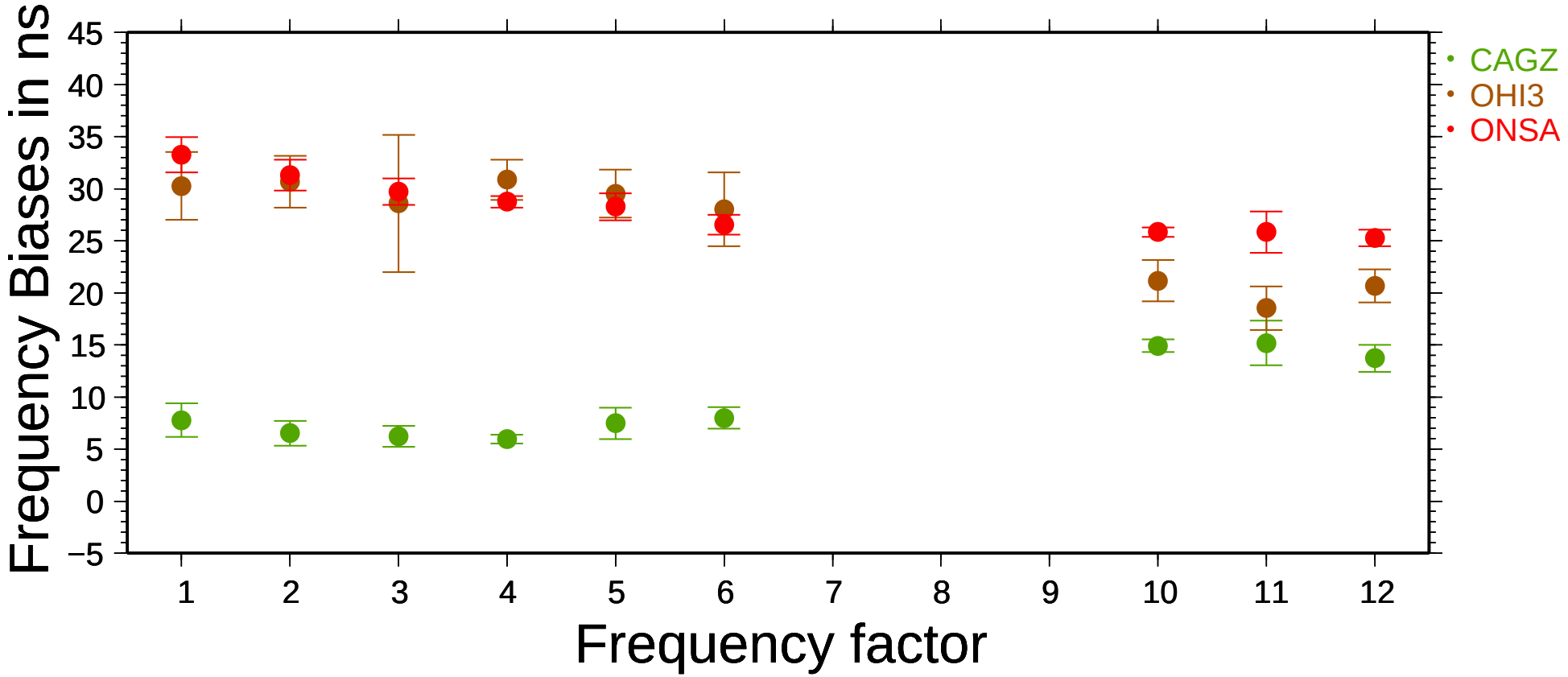
Relative to the GPS frequencies



# Receiver Frequency Bias

## Receiver interfrequency biases for JPS E_GGD

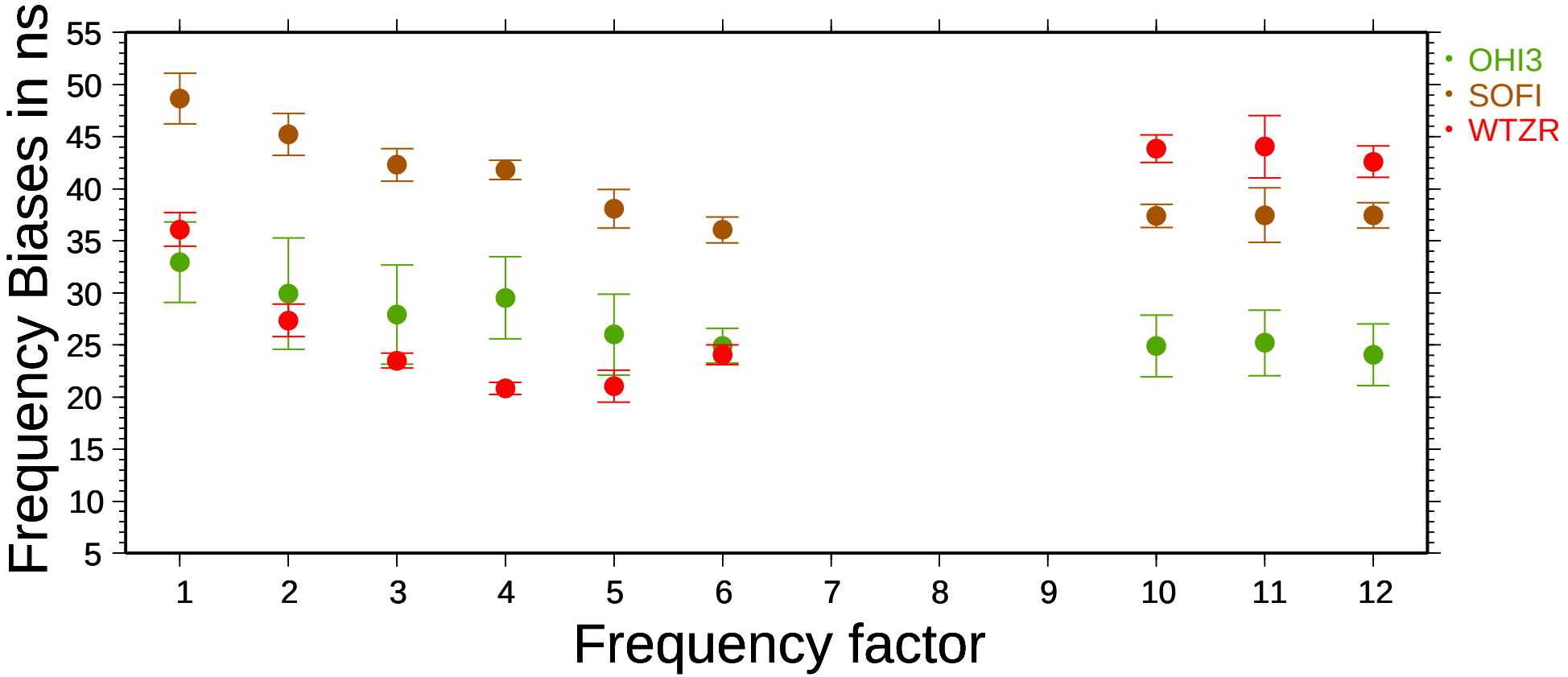
Relative to the GPS frequencies



# Receiver Frequency Bias

## Receiver inter–frequency biases for TPS E_GGD

Relative to the GPS frequencies



## Summary and Outlook

- The consequent combined analysis of measurements from multiple GNSS guarantee the best possible consistency of the products.
- The performance of the GLONASS satellite clocks corresponds to the GPS block II/IIA satellites driven with Cs clocks.
- In the case of GPS and GLONASS no significant difference in the receiver antenna model was detected.

## Summary and Outlook

- The GNSS receivers have not only intersystem but also interfrequency code biases that have to be considered (estimate or introduce) when analyzing GLONASS code data.
- The interfrequency code biases are different for individual receivers, not only for receiver types.
- For the carrier phase observations these biases may be absorbed by the phase ambiguity parameters. They become only relevant if the ambiguities are resolved to their integer values.

## Summary and Outlook

- The launch of more GLONASS satellites and the densification of the GNSS stations in the IGS network will improve the situation for the rigorous GNSS analysis.
- When adding GALILEO as the third GNSS to a combined analysis only an additional intersystem time bias for each receiver is expected.
- The rigorous combined analysis of multiple GNSS allows the consistent processing of data from single system receivers of different GNSS as long as enough multi–system receivers are available.