Rigorously Combined Multi–System GNSS Analysis

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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:

<table>
<thead>
<tr>
<th></th>
<th>GPS</th>
<th>GLONASS</th>
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</thead>
<tbody>
<tr>
<td><strong>Orbits refer to</strong></td>
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<td>PZ–90</td>
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<td>dual–frequency microwave systems</td>
<td></td>
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</tr>
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The observations from all GNSSs are analysed together in one parameter estimation process to get the best possible consistency for all products.

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Multi–System GNSS Analysis

GNSS Station Distribution (used by CODE)

- GPS only
- GPS+GLONASS
Availability of GLONASS satellite clocks
Redundancy for estimated satellite clocks

February 06

MJD


53766 53769 53772 53775

0 5 10 15 20

number of stations
The same stations were used to estimate the GPS and GLONASS satellite clock corrections.
Satellite clock performance

GPS satellites of plane $f$

February 06

$(\text{sat}) - \text{SPT0}$ in ns

MJD

- 53766
- 53768
- 53770
- 53772
- 53774

- G01
- G13
- G14
- G23
- G26
- G29
Satellite clock performance

GLONASS satellites of plane a

February 06
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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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.
Receiver antenna model

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

- AOAD/M_B (OSOD)
- AOAD/M_T (JPLA)
- AOAD/M_T (NONE)
- AOAD/M_T (OSOD)
- ASH701073.1 (DOME)
Receiver Antenna Bias

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Receiver Satellite Bias

Receiver satellite biases for ONSA

only plotted for the GLONASS satellites

![Graph showing receiver satellite biases for ONSA, with satellite biases in ns plotted against MJD from November 05 to March 06. Satellites R01 to R24 are marked.]
Receiver Satellite Bias

Receiver satellite biases for ONSA

only plotted for the GLONASS satellites
Receiver satellite biases for ONSA
Receiver Satellite Bias

Receiver satellite biases for ONSA

Frequency Biases in ns

Frequency factor

1 2 3 4 5 6 7 8 9 10 11 12

-10 -5 0 5 10 15 20 25 30 35 40

• R01
• R02
• R03
• R04
• R05
• R06
• R07
• R08
• R17
• R18
• R19
• R21
• R22
• R23
• R24
Receiver interfrequency biases for ONSA

Relative to the GPS frequencies
Receiver Frequency Bias

Receiver interfrequency biases for ASHTECH Z18

Relative to the GPS frequencies

Frequency Biases in ns

Frequency factor


1 2 3 4 5 6 7 8 9 10 11 12
Receiver Frequency Bias

Receiver interfrequency biases for JPS LEGACY

Relative to the GPS frequencies

Frequency Biases in ns

Frequency factor

- CONZ
- DWH1
- IRKJ
- KHAJ
- KOU1
- LHAZ
- MDVJ
- NOVJ
- REYZ
- SPT0

Frequency Biases in ns

1 2 3 4 5 6 7 8 9 10 11 12

Frequency factor
Receiver Frequency Bias

Receiver interfrequency biases for TPS LEGACY

Relative to the GPS frequencies

![Graph showing receiver interfrequency biases for TPS LEGACY](image-url)

- DARR
- STR2
- UNB1
Receiver Frequency Bias

Receiver interfrequency biases for JPS E_GGD

Relative to the GPS frequencies

Frequency Biases in ns

Frequency factor

- CAGZ
- OH13
- ONSA
Receiver Frequency Bias

Receiver inter–frequency biases for TPS E_GGD

Relative to the GPS frequencies

- OHI3
- SOFI
- WTZR

Frequency Biases in ns

Frequency factor

1 2 3 4 5 6 7 8 9 10 11 12
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.
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.