Generation of GNSS Orbits Based on Microwave and SLR Observations

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Motivation

- GNSS tracking data is regularly collected by both the microwave (IGS/IGLOS) and the SLR observation technique.
- Does it make sense to perform GNSS POD on the basis of the two observation techniques?
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IERS Workshop on Combination

130 GPS-only
27 GNSS
13 SLR

1 GPS: 20,000 MW
1 GLONASS: 3,000 MW
10 SLR (NP)
15 SLR (NP)
Combination strategy (1)

- Combination at level of observations (specifically at level of NEQ information) → MW phase + SLR range
- Computation of common GNSS (GPS + GLONASS) orbit parameters → 41 x 1-day arcs
- Bernese GPS Software (development version)
Combination strategy (2)

Weighting of SLR observations:

- **a** \( \sigma = \infty \)
- **b** \( \sigma = 1 \text{ cm} \)
- **c** \( \sigma = 1 \text{ mm} \)
- **d** \( \sigma = 0.1 \text{ mm} \)
Range residuals (1)

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>-5.7</td>
<td>± 0.10 cm</td>
</tr>
<tr>
<td>b</td>
<td>-5.0</td>
<td>± 0.08 cm</td>
</tr>
<tr>
<td>c</td>
<td>-0.6</td>
<td>± 0.05 cm</td>
</tr>
<tr>
<td>d</td>
<td>-0.1</td>
<td>± 0.03 cm</td>
</tr>
</tbody>
</table>

G05
Range residuals (2)

-0.0 ± 0.20 cm
-0.3 ± 0.09 cm
-0.0 ± 0.04 cm
-0.0 ± 0.04 cm
## Observed range biases

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Bias (cm)</th>
<th>STD (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS G05</td>
<td>-5.7 ± 0.1</td>
<td>1.7</td>
</tr>
<tr>
<td>GPS G06</td>
<td>-5.8 ± 0.2</td>
<td>3.5</td>
</tr>
<tr>
<td>GLONASS R03</td>
<td>-3.1 ± 0.5</td>
<td>5.6</td>
</tr>
<tr>
<td>GLONASS R22</td>
<td>0.0 ± 0.2</td>
<td>5.0</td>
</tr>
<tr>
<td>GLONASS R24</td>
<td>1.1 ± 0.3</td>
<td>6.3</td>
</tr>
</tbody>
</table>
1-day orbit difference at day boundary (1)
1-day orbit difference at day boundary (2)
Conclusions

• From the technical point of view, combined POD analysis of MW and SLR tracking data is no problem.

• Significant biases between the two observation techniques obviously do not allow a rigorous combination for GNSS POD.

• The impact of SLR data on POD is more pronounced for the GLONASS than for the GPS satellite constellation.
Possible explanations for the observed biases

• Mismodelling of GNSS satellite (and receiver) MW antenna phase center offsets and patterns

at present → relative model with unmodelled satellite patterns

new → absolute models, specific to satellite groups or even to each individual satellite (currently under investigation within the IGS!)
Possible explanations for the observed biases

- Mismodelling of GNSS satellite (and receiver) MW antenna phase center offsets and patterns
- Possibly incorrect SLR retro-reflector offsets
- Orbit modeling issues, e.g., solar radiation pressure
Solar radiation pressure modeling

**ROCK vs. CODE**

G06

radial
along-track
out-of-plane

Orbit differences (cm)

DoY 2004

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Solar radiation pressure modeling

**ROCK vs. CODE**

radial
along-track
out-of-plane

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Possible explanations for the observed biases

- Mismodelling of GNSS satellite (and receiver) MW antenna phase center offsets and patterns
- Possibly incorrect SLR retro-reflector offsets
- Orbit modeling issues, e.g., solar radiation pressure
- Issues related to SLR calibration
Issues related to SLR calibration

![Graph showing range residuals over time of day](image)

- Range residuals (cm)
- Time of Day [hours]
Possible explanations for the observed biases

- Mismodelling of GNSS satellite (and receiver) MW antenna phase center offsets and patterns
- Possibly incorrect SLR retro-reflector offsets
- Orbit modeling issues, e.g., solar radiation pressure
- Issues related to SLR calibration
- Unmodelled effects (?)