The space tie between GNSS and SLR

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Overview

- Determination of LRA offsets from SLR data only:
  - «Zero estimation» for a new satellite

- LRA offsets estimated from combined GNSS–SLR solutions:
  - Corrections to official values
LRA offset estimated for a new satellite

- GLONASS–125 (GLONASS–K), launched February 2011
- First assumption: \( \text{LRA}_0 = (0, 0, 0) \)

306 SLR NP;
Mean residual w.r.t. microwave orbit:
\(-1394.2 \text{ mm} \) (RMS 112.5 mm)

Remark:
Microwave antenna offset was not known accurately as well
### LRA offset estimated for a new satellite

- Estimation based only on SLR data:
  - Orbit + ERPs fixed to microwave solution
  - Station coordinates fixed to SLRF2008
  - Assumption: No range biases

#### Solution 1: estimate offset for z-direction (nadir) only

#### Solution 2: estimate offset for x-, y-, z-direction

<table>
<thead>
<tr>
<th>Date</th>
<th># NP</th>
<th>Z [mm]</th>
<th>Z [mm]</th>
<th>X [mm]</th>
<th>Y [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 30</td>
<td>306</td>
<td>1400 ±16.7</td>
<td>1393 ±19.6</td>
<td>-127 ±196.4</td>
<td>-85 ±140.6</td>
</tr>
<tr>
<td>June 5</td>
<td>383</td>
<td>1417 ±13.4</td>
<td>1402 ±16.8</td>
<td>-231 ±155.4</td>
<td>-30 ±117.9</td>
</tr>
<tr>
<td>June 12</td>
<td>494</td>
<td>1442 ± 4.9</td>
<td>1432 ± 5.9</td>
<td>-148 ± 51.5</td>
<td>-19 ± 42.5</td>
</tr>
<tr>
<td>June 21</td>
<td>577</td>
<td>1451 ± 5.4</td>
<td>1448 ± 6.7</td>
<td>-55 ± 59.1</td>
<td>81 ± 47.7</td>
</tr>
</tbody>
</table>

- Official value for 90°: 1473.02 mm
- Official value for 75°: 1469.59 mm
LRA offset estimated for a new satellite

- SLR residuals using z-offsets for LRA:
  - **Type 1:** own estimated offset (1450.8 mm)
  - **Type 2:** official value (1471.3 mm)

Mean Residual = $-1.6 \text{ mm}$, RMS = 135.5 mm

Mean Residual = 37.1 mm, RMS = 133.5 mm
LRA offset estimated for a new satellite

Summary (part 1):

- **LRA Z–offsets** can be determined from SLR data
- Level of accuracy reached: ~ 2 cm
- A few hundreds of SLR NP are needed
- **X–, Y–offsets** are more difficult to determine
- But: Estimation mainly depends on the quality of the orbit based on microwave data
- Estimation could be improved in a fully combined GNSS–SLR analysis (see next part…)
Connection of SLR and GNSS at the GPS / GLONASS satellites ("satellite co-location")

No local ties applied

2000 – 2010
Satellite co-location GPS / GLONASS

Satellite co-locations usable:

2 GPS satellites

+ 

2–6 GLONASS satellites
Co-location at GNSS satellites =

Common orbit parameters from GNSS microwave and SLR range data

1) Microwave part:
Offset of microwave transmitting antenna (SAO)

2) SLR part:
Offset of laser retro-reflector array (LRA)
LRA estimated from multi-year solution

GNSS–SLR solution (A73_6)

- Mean GPS = −1.4 mm
- Mean GLONASS = −16.1 mm

Mean correction w.r.t. the ILRS values:

GPS: −1.4 mm
GLONASS: −16.1 mm
SAO estimated from multi-year solution

Corrections to IGS08 values:

- GPS: $-86.1$ mm
- GLONASS: $-110.4$ mm
Updated IGS08 values (week 1706, 16. Sept 2012):

**GPS:**  
-86.1 mm reduced to **-84.7 mm**  

(GLONASS: only new satellites affected by the update)
Comb 1: Range bias per station, per satellite considered
Comb 2: RGB, SAO, LRA corrections considered

⇒ **Bias** at mm-level (mainly in z-component)
Conclusions

- **Two components** of space tie: SAO, LRA
- Validated within **combined GNSS–SLR solution** (11 years)
- Mean correction for SAO:
  - GPS = -84.7 mm, GLONASS = -110.4 mm
- Mean correction for LRA are small:
  - GPS = -1.4 mm, GLONASS = -16.1 mm
- Impact on other parameters!
- Improvement of the validation / estimation is expected by an **extension** until «now»: several stations are tracking the full GLONASS constellation since mid-2011

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