SLR DATA PROCESSING OF SPHERICAL SATELLITES AT AIUB

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OUTLINE

• Introduction
  – What is SLR
  – Parametrization

• Analysis
  – Compare estimated geodetic parameters of different SLR solutions

• Summary and Outlook
WHAT IS SATELLITE LASER RANGING

Outline:
- Introduction
- Analysis
- Summary and Outlook

• Runtime measurement of a laser beam (e.g. \( \lambda: 532/1064 \, nm \)) from a station to a satellite with retroreflectors

• To determine geodetic parameters, e.g. Earth rotation parameters (ERPs), station coordinates, geocenter

Zimmerwald in Switzerland

Astronomical Institute, University of Bern
## Outline:
- Introduction
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### Satellites

<table>
<thead>
<tr>
<th>Parametrization</th>
<th>LAGEOS-1/2</th>
<th>ETALON-1/2</th>
<th>LARES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osculating elements</td>
<td>$a, e, i, \Omega, \omega, u_0$</td>
<td>1 set per 7 days</td>
<td></td>
</tr>
<tr>
<td>Constant and once-per-rev accelerations</td>
<td>$S_0, S_S, S_C, W_S, W_C$</td>
<td>1 set per 7 days</td>
<td>1 set per 7 days</td>
</tr>
<tr>
<td>Pseudo-stochastic pulses</td>
<td>No pulses</td>
<td>In along-track (twice per day)</td>
<td></td>
</tr>
<tr>
<td>Earth rotation parameters</td>
<td>$X_p, Y_p, UT1 - UTC$</td>
<td>Piecewise-constant</td>
<td>Piecewise-linear</td>
</tr>
<tr>
<td>Geocenter coordinates</td>
<td>1 set per 7 days</td>
<td>Fixed Geocenter</td>
<td></td>
</tr>
<tr>
<td>Station coordinates</td>
<td>1 set per 7 days</td>
<td>Loosely constrained</td>
<td>NNR and NNT solution</td>
</tr>
<tr>
<td>Range biases</td>
<td>1 set per 7 days for selected stations</td>
<td>all stations</td>
<td></td>
</tr>
</tbody>
</table>

### Parametrization Diagram

- **PWC**
  - Polar motion
  - UT1-UTC / LoD

- **PWL**
  - UT1-UTC

### Notes
- LAGEOS + ETALON + LARES (7-day arc)
- LAGEOS + ETALON (7-day arc)
- LAGEOS + ETALON + LARES (daily dyn. Param. for LARES)

### Parameters
- EST. GEOCENTER
- FIXED GEOCENTER
- LOOSELY CONSTRAINT
- NNT/NNR

### References
- Sośnica, 2015
Outline:
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DIFFERENT SLR-SOLUTIONS

Outline:
• Introduction
• Analysis
• Summary and Outlook

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DIFFERENT SLR-SOLUTIONS
COMPARISON OF EARTH ROTATION PARAMETERS

Outline:
• Introduction
• Analysis (PWC)
  – ERPs
  – Station coord.
  – Geocenter
• Summary and Outlook

Abbreviations:
(S1): LAGEOS+ETALON (7-day arcs)
(S2): LAGEOS+ETALON+LARES (7-day arcs)
(S3): LAGEOS+ETALON+LARES (daily dyn. Param. for LARES)

• Several outliers
  – LARES can stabilize
  – caused by LARES

• Sensitive to the a priori orbits through the screening
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Comparision of Estimated ERPs W.R.T. C04-Series (ITRF14) at 12H-Epoch W/O Outliers

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- \( S3 \): LAGEOS+ETALON+LARES (daily dyn. Param. for LARES)

<table>
<thead>
<tr>
<th>Used satellites</th>
<th>Station coordinates</th>
<th>Geocenter</th>
<th>X pole [( \mu as )]</th>
<th>Y pole [( \mu as )]</th>
<th>UT1-UTC [( \mu s )]</th>
</tr>
</thead>
<tbody>
<tr>
<td>(S1): LAGEOS+ETALON</td>
<td>Loosely fixed NNT/NNR</td>
<td>estimated</td>
<td>139.3 234.9</td>
<td>-58.8 285.1</td>
<td>-3.6 19.3</td>
</tr>
<tr>
<td>(S2): LAGEOS+ETALON+LARES (7-day arcs)</td>
<td>Loosely fixed NNT/NNR</td>
<td>estimated</td>
<td>-87.3 395.7</td>
<td>-77.2 362.4</td>
<td>-3.0 22.9</td>
</tr>
<tr>
<td>(S3): LAGEOS+ETALON+LARES (daily dyn. Parameters for LARES)</td>
<td>Loosely fixed NNT/NNR</td>
<td>estimated</td>
<td>-269 466.4</td>
<td>-462.9 750.9</td>
<td>-3.3 18.9</td>
</tr>
</tbody>
</table>

- Abbreviations:
  - NNT/NNR: estimated
  - fixed

- Solutions X pole [\( \mu as \)] Y pole [\( \mu as \)] UT1-UTC [\( \mu s \)]
### COMPARISON OF EARTH ROTATION PARAMETERS

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### Conclusion:
- Use a good datum definition
- LARES parametrization has to be extended as for example in (S3)
- If a good parametrization is used, the estimation of geocenter coordinates can slightly improve the ERPs

<table>
<thead>
<tr>
<th>Solutions</th>
<th>Used satellites</th>
<th>Station coordinates</th>
<th>Geocenter</th>
<th>X pole [μas]</th>
<th>Y pole [μas]</th>
<th>UT1-UTC [μs]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bias</td>
<td>WRMS</td>
<td>Bias</td>
<td>WRMS</td>
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</tbody>
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- Conclusion: Use a good datum definition
- LARES parametrization has to be extended as for example in (S3)
- If a good parametrization is used, the estimation of geocenter coordinates can slightly improve the ERPs
COMPARISON OF HELMERT TRANSFORMATION

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• If a good LARES orbit parametrization is used, the RMS of Helmert transformations can be decreased
COMPARISON OF THE GEOCENTER

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• The time series of the geocenter from solution (S3) fits better to (S1) than (S2)
Outline:
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DIFFERENT SLR-SOLUTIONS

- ORBIT PARAMETRIZATION
  - S1: LAGEOS+ETALON (7-day arc)
  - S2: LAGEOS+ETALON+LARES (7-day arc)
  - S3: LAGEOS+ETALON+LARES (daily dyn. Param. for LARES)

- ERPs
  - PWL

- STATION COORDINATES
  - NNT/NNR
    - LOOSELY CONSTRAINT
      - EST. GEOCENTER
      - FIXED GEOCENTER
  - PWL
    - NNT/NNR
      - LOOSELY CONSTRAINT
      - EST. GEOCENTER
      - FIXED GEOCENTER

- GEOCENTER
  - NNT/NNR
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COMPARISON OF EARTH ROTATION PARAMETERS

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Conclusion:
Piecewise-linear parametrization of ERPs can improve the solution
Summary:
• We successfully included LARES with two different orbit parametrizations in our SLR solutions
• A good datum definition is needed
• Piecewise-linear parametrization of ERPs improves the quality of the ERPs

Outlook:
• Further investigations of PWL parametrization of ERPs
• Co-estimation of low-degree gravity field coefficients
REFERENCES