Geocenter Motion: Causes and Modeling Approaches

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Outline

- “SLR network origin to geocenter” vector
- Variations due to mass redistribution
- SLR monitoring of geocenter variations
- Examples of SLR results’ application
- Summary and Conclusions

We gratefully acknowledge the support of the ILRS and their network for making their SLR tracking data available to us for this work, as well as the GRACE Mission Project for the release of GSM products.
We concentrate here on Earth’s “Center of Mass”, the geocenter, the fidelity and accuracy with which SLR defines its average location over decades and monitors its seasonal variations associated with the redistribution of geophysical fluids.
## Secular Geophysical Signals

<table>
<thead>
<tr>
<th>Source</th>
<th>Magnitude</th>
<th>Induced motion</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level</td>
<td>1.2 mm/y</td>
<td>0.064 ±0.02 mm/y</td>
<td>2</td>
</tr>
<tr>
<td>Ice sheets (G)</td>
<td>2 mm/y</td>
<td>0.046±0.20 mm/y</td>
<td>2</td>
</tr>
<tr>
<td>Tectonics</td>
<td>AMO-2</td>
<td>0.309±0.05 mm/y</td>
<td>2</td>
</tr>
<tr>
<td>Postglacial rebound</td>
<td>ICE-3G</td>
<td>0.2 - 0.5 mm/y</td>
<td>1</td>
</tr>
</tbody>
</table>

(1) : Marianne Greff-Lefftz (2000)  
(2) : Yu. Barkin (1997)
The ILRS Network

North Sites: 16

South Sites: 6 (7)

~ 135° gap in longitude!
The ILRS Network Yield

Angermann & Müller, 2007

LAGEOS 1 & 2 SLR network stations. The bars show the number of observed normal points from 1993 until 2007.
Geocenter from SLR to LAGEOS

Geocenter with respect to ITRF2000 with secular rates removed, raw (green) and 30-day smoothed (red) values [SSC(JCET) 06 L25].

Annual term amplitude: 2.0 mm

Annual term amplitude: 1.1 mm

Annual term amplitude: 6.2 mm
Subset Solutions for an SLR TRF

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- All the data
- 1st vs. 2nd Half
- “ODD” Weeks
- “EVEN” Weeks
- 1st “every 3rd”
- 2nd “every 3rd”
- 3rd “every 3rd”
- 1/3 of data set
- 1/4 of data set
# TRF Subset Solutions Statistics [mm]

| Case | $\Delta X$ | $\sigma_{\Delta X}$ | $\Delta Y$ | $\sigma_{\Delta Y}$ | $\Delta Z$ | $\sigma_{\Delta Z}$ | 3D $|\Delta|$ | $\sigma_{3D \Delta}$ |
|------|----------|---------------------|----------|---------------------|----------|---------------------|-------------|---------------------|
| 3 Odd  | -8.37   | $\pm 10.91$         | 19.25   | $\pm 10.78$         | -4.20   | $\pm 10.32$         | 21          | $\pm 17$           |
| 4 Even | -12.62  | $\pm 8.93$          | 5.15    | $\pm 8.82$          | -12.50  | $\pm 8.44$          | 18          | $\pm 16$           |
| 1 1/2  | -41.20  | $\pm 35.82$         | 6.26    | $\pm 35.38$         | -10.10  | $\pm 33.86$         | 43          | $\pm 61$           |
| 2      | 1.74    | $\pm 6.76$          | 8.06    | $\pm 6.68$          | 7.28    | $\pm 6.39$          | 11          | $\pm 11$           |
| 15 1/4 | -60.49  | $\pm 23.68$         | 57.43   | $\pm 23.39$         | 7.48    | $\pm 22.39$         | 84          | $\pm 40$           |
| 16     | 18.65   | $\pm 31.40$         | -57.81  | $\pm 30.88$         | -6.19   | $\pm 29.50$         | 61          | $\pm 53$           |
| 17     | -0.27   | $\pm 18.01$         | -4.74   | $\pm 17.79$         | 15.72   | $\pm 17.03$         | 16          | $\pm 31$           |
| 18     | 2.07    | $\pm 12.29$         | 7.16    | $\pm 12.18$         | 1.73    | $\pm 11.60$         | 8           | $\pm 21$           |
Table 1. Scatter of similarity transformation parameters w.r.t. ITRF2000 for successive weekly ILRS solutions for 2006 (offsets in mm, scale in ppb).

<table>
<thead>
<tr>
<th>Individual</th>
<th></th>
<th>Tx</th>
<th>Ty</th>
<th>Tz</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASI</td>
<td></td>
<td>3.8</td>
<td>3.1</td>
<td>8.5</td>
<td>1.2</td>
</tr>
<tr>
<td>BKG</td>
<td></td>
<td>4.0</td>
<td>1.6</td>
<td>2.4</td>
<td>0.6</td>
</tr>
<tr>
<td>DGFI</td>
<td></td>
<td>4.7</td>
<td>3.9</td>
<td>9.0</td>
<td>0.8</td>
</tr>
<tr>
<td>GFZ</td>
<td></td>
<td>4.2</td>
<td>2.7</td>
<td>6.9</td>
<td>0.9</td>
</tr>
<tr>
<td>JCET</td>
<td></td>
<td>3.0</td>
<td>2.2</td>
<td>7.1</td>
<td>0.9</td>
</tr>
<tr>
<td>NSGF</td>
<td></td>
<td>6.1</td>
<td>7.3</td>
<td>12.0</td>
<td>1.4</td>
</tr>
<tr>
<td>Combination</td>
<td>ILRS-A</td>
<td>2.8</td>
<td>2.2</td>
<td>6.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Our Future Goals

- Future networks should deliver consistently and reliably:
  - <1 mm epoch position, and
  - < 0.1 mm/y secular change
Why 1 mm / 0.1 mm/y?

ITRF2005: 3.3 +/- 0.07 mm/yr

- MSL Rates (mm/yr)
  - 1993-2007 = 3.33 ± 0.07 (MOG2D)
    = 3.36 ± 0.10 (No IB)
  - First 7 years = 2.75 ± 0.21 (MOG2D)
    = 2.53 ± 0.23 (No IB)
  - Last 7 years = 3.76 ± 0.14 (MOG2D)
    = 3.99 ± 0.25 (No IB)

For every 1 mm/y Z-trend in the TRF origin, sea-level rates are affected by ~ 0.2 mm/y

Lemoine et al. (2008), EGU2008-A-11368

Beckley et al. (2007), GRL, Fig 4
Geocenter Monitoring (Z)

\[ T_{zc} = T_{zc2000} + T_zc^r(t-2000) \]

<table>
<thead>
<tr>
<th>Value</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>m1</td>
<td>0.91063</td>
</tr>
<tr>
<td>m2</td>
<td>1.6981</td>
</tr>
<tr>
<td>m3</td>
<td>-4.9414</td>
</tr>
<tr>
<td>m4</td>
<td>-4.791</td>
</tr>
<tr>
<td>m5</td>
<td>-6.052</td>
</tr>
<tr>
<td>m6</td>
<td>1.1947</td>
</tr>
<tr>
<td>m7</td>
<td>-2.7918</td>
</tr>
<tr>
<td>m8</td>
<td>0.40715</td>
</tr>
<tr>
<td>Chisq</td>
<td>63378</td>
</tr>
<tr>
<td>R</td>
<td>0.69271</td>
</tr>
</tbody>
</table>

ICE5G + Greenland & Antarctica melting rates:
G-tail @ 3 mm/yr + A-tail @ 1 mm/yr \( \Rightarrow \Delta Z \approx 1 \text{ mm/yr} \)

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Geocenter Correction for POD (1)

Radial orbit Differences

GSFC(SLR+DORIS) - JPL(GPS)

WITHOUT Geocenter correction

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Geocenter Correction for POD (2)

Radial orbit Differences
GSFC (SLR+DORIS) - JPL (GPS)
Using ITRF2005 (no correction)

Radial orbit Differences
GSFC (SLR+DORIS) - JPL (GPS)
WITH Geocenter correction

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Summary - Conclusions

- Tracking-network origin definition varies from week to week due to geophysical fluid redistribution in Earth system
- ILRS monitors this at the “few mm” level including linear rates
- SLR network non-uniformity and data yield result in variable quality of the above results over the past decade
- Future requirement of definition at epoch at < 1mm and rates of < 0.1mm/y are dictated by MSL change studies
- Application of SLR monitoring of “geocenter” WRT previous ITRF (2000) in altimetry data reductions produces MSL results qualitatively equivalent to those derived from the new ITRF (2005), demonstrating SLR’s ability to accurately monitor these variations