GIOVE-A and GPS-35/36 satellite orbits: analysis of dynamical properties based on SLR-only tracking data

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Overview

- GIOVE-A, GPS 35/36 SLR-orbit estimation strategy
- Data set
- Orbit analysis of GIOVE-A
- Orbit analysis of GPS 35/36
- Conclusions and perspectives
SLR-orbit estimation strategy

- For the orbit fitting we are using GINS 6.1 GPS/SLR/DORIS/VLBI software.
- The orbit analysis for GIOVE-A examines the overlap agreement of consecutive 2-day SLR only arcs.
- The orbit analysis for GPS 35/36 examines the overlap agreement between 10-day SLR only arcs and the IGS precise final orbits.

\[
\begin{align*}
\text{rms}_{\text{overlap}} &= \sqrt{\frac{\left(\mathbf{x}_{\text{GINS/GIOVE/GPS}} - \mathbf{x}_{\text{IGS/GINS/GPS/GIOVE}}\right)^2}{n}} \\
\text{rms3D} &= \sqrt{\text{rms}_{\text{Radial}}^2 + \text{rms}_{\text{Along}}^2 + \text{rms}_{\text{Cross}}^2}
\end{align*}
\]
SLR-orbit estimation strategy

- For GIOVE-a, the solar radiation pressure modelling we are using is a new Box and Wing model. (Parameterisation for 8 surfaces and a-priori reflectivity and specularity coefficients).

  X : completes the system  
  Y : points along the solar panels  
  D : points towards the sun
## SLR-orbit estimation strategy

<table>
<thead>
<tr>
<th><strong>GINS software</strong></th>
<th><strong>GPS 36/35</strong></th>
<th><strong>GIOVE-A</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity field</td>
<td>GRIM5_c1 (20x20)</td>
<td>EIGEN_GL04S (20x20)</td>
</tr>
<tr>
<td>Solar Radiation Pressure</td>
<td>Box and Wing</td>
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</tr>
<tr>
<td>Datum definition</td>
<td>ITRF2000, EOPC04</td>
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<tr>
<td>Tidal displacements</td>
<td>IERS 2003</td>
<td>IERS 2003</td>
</tr>
<tr>
<td>Atm. + Ocean loading, Troposphere</td>
<td>ECMWF, FES2004, Marinni-Murray</td>
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</tr>
<tr>
<td>Satellite retro-reflector offsets</td>
<td>x=-0.863, y=0.524, z=-0.658</td>
<td>x=0.828, y=0.655, z=-0.701</td>
</tr>
<tr>
<td>Attitude model</td>
<td>X, Y, D</td>
<td>X, Y, D</td>
</tr>
<tr>
<td>Albedo and infrarouge model</td>
<td>Analytical model (10dx10d)</td>
<td>Analytical model (10dx10d)</td>
</tr>
<tr>
<td>Numerical integration</td>
<td>Cowell 8th order, step=180s</td>
<td>Cowell 8th order step=180s</td>
</tr>
<tr>
<td>Adjustment</td>
<td>Weighted LSQ (1cm SLR)</td>
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</tr>
<tr>
<td></td>
<td>6 orbital param., 1 SRP coeff., 1 Yb,</td>
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</tr>
<tr>
<td></td>
<td>1 X,D per-rev/2-days</td>
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</tr>
<tr>
<td>Orbital param.</td>
<td>Init. cond. from broadcasted ephemerides</td>
<td>Init. cond. from analytic integration based on SLR measurements</td>
</tr>
</tbody>
</table>
Data set

GPS 35/36:
- Fitted arcs of 2, 10, and 30 days

GIOVE-A:
- 2311 SLR normal points for June, July, August 2006.
- Fitted arcs of 2, 10, 30, 90 days

3 months GIOVE-A SLR campaign

16/10/2006
Canberra, Australia
Overlaps of 2 days GIOVE-A SLR arcs in the period of 05/06/2006-19/06/2006

STD of the orbit overlap in radial direction

RMS of the orbit overlap in radial direction

SLR observations of the GIOVE-A satellite

Yb, 2 per-rev terms

Manœuvre ?

16/10/2006
Canberra, Australia
10-day overlap of a GIOVE 30-day arc versus a 10–day arc in the beginning of June 2006

GINS SLR global residuals for a 90-day, 30-day, and 10-day GIOVE arc
Orbit analysis of GPS35/36

ASCENDING NODE * MEAN = 7.967e-08 RMS = 2.138e-09 (rad)

ARC. OF PERIGEE * MEAN = 6.526e-07 RMS = 1.589e-07 (rad)

ARC. OF PER. + MEAN ANOM. * MEAN = -2.269e-08 RMS = 2.872e-09 (rad)
### Helmert transformation wrt. the IGS microwave orbits for GPS35 doy 157-167

- 0.786898E-02 +/- 0.997E-02  
  1: translation in x - (m)
- -0.485564E-03 +/- 0.997E-02  
  2: translation in y - (m)
- 0.598395E-01 +/- 0.997E-02  
  3: translation in z - (m)
- 0.620124E-09 +/- 0.375E-09  
  4: scale factor (ppb)
- -0.336947E-03 +/- 0.947E-04  
  5: rotation in x (arcsec)
- 0.135668E-04 +/- 0.956E-04  
  6: rotation in y (arcsec)
- -0.242881E-02 +/- 0.942E-04  
  7: rotation in z (arcsec)
- 0.190437E-02 +/- 0.534E-02  
  4: scale factor (m)

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### Helmert transformation wrt. the IGS microwave orbits for GPS36 doy 157-167

- 0.222380E-02 +/- 0.531E-02  
  1: translation in x - (m)
- 0.836202E-03 +/- 0.531E-02  
  2: translation in y - (m)
- 0.453187E-01 +/- 0.531E-02  
  3: translation in z - (m)
- 0.712820E-10 +/- 0.200E-09  
  4: scale factor (ppb)
- -0.303654E-03 +/- 0.508E-04  
  5: rotation in x (arcsec)
- 0.446041E-04 +/- 0.505E-04  
  6: rotation in y (arcsec)
- -0.145764E-02 +/- 0.501E-04  
  7: rotation in z (arcsec)
- 0.190437E-02 +/- 0.534E-02  
  4: scale factor (m)
Mean equations of motion obtained with an analytical averaging (5th order in J_2), based on Lie transformations, which are integrated in a numerical way
- Earth gravity field (coupling effects J_2J_n up to n=40), Moon & Sun effects
- Radiation pressure, …

Short periodic terms (with great amplitude) filtered from osculating orbits thanks to a filtering approach

One single arc fitted on « mean observed elements » in view of:
- Gravitational parameters: GM, post-glacial rebound, …
- Non gravitational effects: dynamical modelling, error budget
- Mission analysis

16/10/2006 Canberra, Australia
Example: residuals obtained on the ascending node of LAGEOS-1

ASCENDING NODE * MEAN = 8.449e-18 RMS = 1.006e-07 (rad)

GIOVE-A
Day 20620 (12h)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-major axis (km)</td>
<td>0.29634097232910E+08</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>0.83825404091530E-03</td>
</tr>
<tr>
<td>Inclination (rad)</td>
<td>0.97770690917969E+00</td>
</tr>
<tr>
<td>Ascending Node (rad)</td>
<td>0.32480748016896E+01</td>
</tr>
<tr>
<td>Argument of perigee (rad)</td>
<td>0.57041260521250E+01</td>
</tr>
<tr>
<td>Mean anomaly (rad)</td>
<td>0.31670464980501E+01</td>
</tr>
</tbody>
</table>
Dynamical properties (1/2)

Metric elements

- Resonance effects on semi-major axis (GPS orbit)

QuickTime™ et un décompresseur TIFF (LZW) sont requis pour visionner cette image.
Dynamical properties (2/2)

Angular elements

- GIOVE-A argument of perigee

**GIOVE-A / GPS36:**

<table>
<thead>
<tr>
<th></th>
<th>GIOVE-A</th>
<th>GPS36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perigee period (day)</td>
<td>27843</td>
<td>13825</td>
</tr>
<tr>
<td>Ascending node period (day)</td>
<td>13979</td>
<td>8948</td>
</tr>
</tbody>
</table>

16/10/2006

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Conclusions and perspectives

GIOVE - A
- We have calculated 2, 10, 30-day GIOVE-A SLR only orbits with an internal accuracy of 5-10 cm in radial direction.
- For 90, 30 and 10-day arcs the orbit dynamics is a stronger constraint than for 2-day arcs.
- Our SRP modelling is still under investigation. An adjustment procedure of the specularity and reflectivity coefficients of the satellite is on the way together with a new empirical SRP modelling.
- The residual level for the 10 and 2 days arcs are below the level of 10 cm.
- Further investigation would be to know the exact date of a change in the orbit as clearly seen in the 2-days arcs, and introduce a new set of accelerations.

GPS 35/36
- The overall agreement of the SLR orbits compared wrt. the IGS final orbits is of the order of 1-3 cm in Radial, 5-10 cm in Along and 25-40 cm in Cross-track.
- The internal precision stays itself in the level of 30-40 cm 3DRMS.
- Offset values for the translation coefficients in Z verify once again the effect of the non-homogeneity of SLR tracking stations. A similar explanation can be given for the lack of consistency between the relative scales of SLR and microwave orbits.