Latest GNSS orbit modelling improvement at CODE

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Latest GNSS orbit modelling improvement at CODE:

1. Motivation to review the radiation pressure modelling
2. Update of the CODE radiation pressure model
3. Verification of the updated model
4. Summary and Outlook
The radiation pressure modelling at CODE is based on an empirical model from Tim Springer:

- The a priori model consists of nearly 20 parameters for several resonance periods of the satellite revolution (Springer et al., 1999).
- On top of this model, up to nine parameters may be estimated from the observations (Extended CODE model; Beutler et al., 1994).
Motivation

- The radiation pressure modelling at CODE is based on an empirical model from Tim Springer:
  - The a priori model consist of nearly 20 parameters for several resonance periods of the satellite revolution (Springer et al., 1999).
  - On top of this model up to nine parameters may be estimated from the observations (Extended CODE model; Beutler et al., 1994).

- After nearly seven year a review of the model became necessary
  - to verify the model parameters for the GPS satellites,
  - to estimate model parameters for launched GPS satellites (since that time), and
  - to obtain a first set of model parameters for GLONASS satellites.
Motivation

SLR residuals in cm to CODE final orbits (G05 and G06)

Urschel et al., 2007
Parameters of the updated CODE radiation pressure model are estimated by:
- moving seven-day fits of CODE final orbits
- some of the parameters are block–specific others individual for each satellite

A priori radiation pressure models for comparison:
- NONE: no a priori model
- ROCK: ROCK model (Fliegel and Gallini, 1996)
- CODE’99: old CODE model as published by Spinger, 1999
- CODE’07: updated CODE model

The full orbit estimation was performed based on the different a priori models. Estimated RPR parameters: three constant and once per revolution for one component.
Updated CODE Radiation Pressure Model

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Comparison between the a priori radiation pressure models

Satellite → Sun component

Satellite G15 (Block II)

unit: m/s² · 10⁻⁹
Updated CODE Radiation Pressure Model

Comparison between the a priori radiation pressure models

satellite→Sun component

Satellite G05 (Block IIA)

unit: m/s² · 10⁻⁹
Updated CODE Radiation Pressure Model

Comparison between the a priori radiation pressure models
satellite→Sun component

Satellite G13 (Block IIR–A)

unit: m/s^2 \cdot 10^{-9}
Comparison between the a priori radiation pressure models supplementing component

Satellite G15 (Block II)

unit: $\text{m/s}^2 \cdot 10^{-9}$
Updated CODE Radiation Pressure Model

Comparison between the a priori radiation pressure models supplementing component

Satellite G05 (Block IIA)

unit: m/s² · 10⁻⁹
Comparison between the a priori radiation pressure models supplementing component

Satellite G13 (Block IIR–A)

unit: m/s² · 10⁻⁹
Updated CODE Radiation Pressure Model

Differences in the estimated orbits using different a priori RPR models

a priori RPR model: ROCK – CODE’07

Satellite G05 (Block IIA)

RMS: 1.9 cm
Differences in the estimated orbits using different a priori RPR models

a priori RPR model: CODE’99 – CODE’07

Satellite G05 (Block IIA)

RMS: 0.5 cm
Differences in the estimated orbits using different a priori RPR models

a priori RPR model: NONE – CODE’07

Satellite G05 (Block IIA)

RMS: 0.3 cm
Differences in the estimated orbits using different a priori RPR models

RMS of the differences w.r.t. the CODE’07 a priori model over 10 days.

<table>
<thead>
<tr>
<th>PRN</th>
<th>ROCK</th>
<th>CODE’99</th>
<th>NONE</th>
<th>PRN</th>
<th>ROCK</th>
<th>CODE’99</th>
<th>NONE</th>
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<tr>
<td>G15</td>
<td>1.9</td>
<td>0.5</td>
<td>0.4</td>
<td>G10</td>
<td>1.7</td>
<td>0.2</td>
<td>0.4</td>
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<tr>
<td>G01</td>
<td>1.8</td>
<td>0.2</td>
<td>0.2</td>
<td>G13</td>
<td>1.9</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>G03</td>
<td>0.8</td>
<td>0.3</td>
<td>0.2</td>
<td>G24</td>
<td>1.6</td>
<td>0.4</td>
<td>0.3</td>
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<tr>
<td>G04</td>
<td>1.4</td>
<td>0.3</td>
<td>0.3</td>
<td>G25</td>
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<td>0.2</td>
<td>0.4</td>
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<tr>
<td>G05</td>
<td>1.9</td>
<td>0.5</td>
<td>0.4</td>
<td>G26</td>
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<td>0.3</td>
<td>0.2</td>
<td>G27</td>
<td>2.3</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>G07</td>
<td>0.6</td>
<td>0.3</td>
<td>0.2</td>
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<td>1.6</td>
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<tr>
<td>G08</td>
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<td>0.5</td>
<td>G29</td>
<td>1.6</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>G09</td>
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<td>0.3</td>
<td>0.6</td>
<td>G30</td>
<td>1.9</td>
<td>0.4</td>
<td>0.3</td>
</tr>
</tbody>
</table>

unit: cm
Verification of Radiation Pressure Models

- A long-term prediction over 15 days is used to verify the radiation pressure models.

- Rules for the orbit prediction:
  - Integration over three days of the estimated orbits
  - Apart from the six initial osculating elements only the direct radiation pressure component is estimated. All other components are only taken from the models.

- The predicted orbits are compared with the estimated orbit for the corresponding day.

- The experiment was carried out for three months at the end of year 2005.
Verification of Radiation Pressure Models

Differences in the estimated and predicted orbits using different a priori RPR models

Orbit diff. in m

Satellite G27 (Block IIA)
Verification of Radiation Pressure Models

Differences in the estimated and predicted orbits using different a priori RPR models

Satellite G27 (Block IIA)
Verification of Radiation Pressure Models

Differences in the estimated and predicted orbits using different a priori RPR models

Satellite G27 (Block IIA)
Verification of Radiation Pressure Models

Differences in the estimated and predicted orbits using different a priori RPR models

![Graph showing differences in orbit estimation and prediction](image)

- **Satellite G27 (Block IIA)**
  - MJD:
    - 53580
    - 53585
    - 53590
    - 53595
  - Orbit diff. in m:
    - NONE
    - ROCK
    - CODE 99
    - CODE 07

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Dach et al.: GNSS orbit modelling at CODE - p. 11/15
Verification of Radiation Pressure Models

Differences in the estimated and predicted (15 days) orbits using different a priori RPR models

Satellite G27 (Block IIA)
Verification of Radiation Pressure Models

Differences in the estimated and predicted (15 days) orbits using different a priori RPR models

Satellite G09 (Block IIA)
Verification of Radiation Pressure Models

Differences in the estimated and predicted (15 days) orbits using different a priori RPR models

Satellite G24 (Block IIA)
Verification of Radiation Pressure Models

Differences in the estimated and predicted (15 days) orbits using different a priori RPR models

Satellite G14 (Block IIR–A)
Verification of Radiation Pressure Models

Differences in the estimated and predicted (15 days) orbits using different a priori RPR models

Satellite G21 (Block IIR–A)
Verification of Radiation Pressure Pressure Models

Differences in the estimated and predicted (15 days) orbits using different a priori RPR models

Satellite G02 (Block IIR–B)
Verification of Radiation Pressure Models

Mean differences in the estimated and predicted (15 days) orbits using different a priori RPR models

RMS orbit diff. in m


NONE ROCK CODE 99 CODE 07

Block II Block IIA Block IIR−A Block IIR−B
Verification of Radiation Pressure Models

Mean differences in the estimated and predicted (15 days) orbits using different a priori RPR models

RMS orbit diff. in m

- R01
- R02
- R03
- R04
- R05
- R08
- R19
- R20
- R21
- R22
- R06
- R07
- R23
- R24

GLONASS
GLONASS-M
NONE
CODE 07
Conclusions

- The CODE radiation pressure model that is used as a priori for the orbit determination at CODE has been updated:
  - to verify the existing CODE model for old GPS satellites
  - to extend the model to the new GPS and GLONASS satellites

- The quality of the new model is comparable with the quality of the old one.

- A long–term prediction based on the radiation pressure models has shown:
  - an advantage of the CODE model w.r.t. the ROCK model, especially for Block IIA GPS satellites.
  - an improvement for the radiation pressure modelling for most of the GLONASS satellites.

- The update of the CODE radiation pressure model shall be automatized in the frame of the CODE’s IGS activities.
Outlook

More on the updated CODE radiation pressure modelling during this week:

Claudia Urschl: Assessing the quality of GNSS orbit models using SLR
Luca Ostini: Near-seasonal periods in GNSS station time series

Both papers will be presented tomorrow in the Session G1:
*The impact of technique errors on reference frame accuracy and stability.*