[EGU2017-15532]
Effect of the Accelerometer Calibration Method on AIUB’s GRACE Monthly Gravity Field Solution

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EGU General Assembly 2017
23-28 April, 2017
Vienna, Austria
Contents

Please click or touch the button to view the detailed contents.

Introduction  Method  Result

Conclusion  Reference  EGSIEEM Project
**Introduction**

**GRACE Mission by NASA/DLR**

- GPS Measurements + K-band Measurements + other Measurements

- Monthly Gravity Field Solutions
One of the Methods to Improve the Quality is

Accelerometer Data Calibration

- **On-board Accelerometer**
  - Measuring nongravitational forces acting on the satellites
    (e.g. perturbing forces by air drag, ...)

- **Official GRACE ACC1B Data**
  - contain instrument scale and bias in the linear accelerations
  \( \rightarrow \) Calibration is required.
Objective

GRACE monthly gravity field solutions by the AIUB Processing Center

- estimates the scaling factors in three directions since the release 2 monthly gravity field solutions (Meyer et al. 2016)

using Celestial Mechanics Approach (Beutler et al. 2010a, 2010b)

To investigate the effect of the accelerometer data calibration in the Celestial Mechanics Approach using the stochastic pulses/piece-wise constant accelerations

- Interactions between the stochastic parameters and the scaling factors for the accelerometer data calibration
Method: Accelerometer Data Calibration

- **Calibration equation:**
  \[ \mathbf{a}_{\text{Calibrated}} = S \cdot \mathbf{a}_{\text{Measured}} + \mathbf{b} \]

  - \( \mathbf{a}_{\text{Calibrated}} \): Calibrated Acceleration
  - \( \mathbf{a}_{\text{Measured}} \): Measured Acceleration by the GRACE accelerometers
  - \( S \): Scale matrix
  - \( \mathbf{b} \): bias

- **Scaling Matrix:**
  \[ S = \begin{bmatrix} S_x & S_{xy} & S_{xz} \\ S_{yx} & S_y & S_{yz} \\ S_{zx} & S_{zy} & S_z \end{bmatrix} \]

  - Main diagonals: estimated once per day
  - Usually, the off-diagonal terms are assumed to be 0:
    \[ S_{xy} = S_{xz} = S_{yx} = S_{yz} = S_{zx} = S_{zy} = 0 \]
Celestial Mechanics Approach (CMA)

- A processing method to produce gravity field solutions as well as satellite orbits (Beutler et al. 2010a, 2010b)
- Used at the AIUB processing center via the Bernese GNSS Software
- Stochastic parameters

**Stochastic Pulse/Piece-wise Constant Accelerations**

- CMA-specific parameters:
  - *Instantaneous velocity changes* in three directions at particular epochs or
  - *Piece-wise constant accelerations* in three directions over a certain time interval

- Stochastic pulse/Piece-wise constant acceleration is varied by *contraint of RMS* and *frequency* (every 15 minutes for the GRACE orbits)
## Processing Details

<table>
<thead>
<tr>
<th>Type/Models</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reference Frame</strong></td>
<td>• Satellite RSW frame</td>
</tr>
<tr>
<td></td>
<td>• GRACE Instrument (Accelerometer) frame</td>
</tr>
<tr>
<td></td>
<td>• ECI J2000</td>
</tr>
<tr>
<td><strong>Processing Strategy (SW)</strong></td>
<td>Celestial Mechanics Approach (Bernese GNSS Software)</td>
</tr>
<tr>
<td><strong>Estimated Parameters</strong></td>
<td>• GRACE Orbital Elements</td>
</tr>
<tr>
<td></td>
<td>• 3-dimensional Scaling Factors (Once per day) and Offsets (Once per day) for Accelerometer Data Calibration</td>
</tr>
<tr>
<td></td>
<td>• Stochastic Pulses (every 15 minutes)</td>
</tr>
<tr>
<td><strong>Input Data and Models</strong></td>
<td>(Identical to AIUB GRACE Monthly Gravity Fields Release 2: Meyer et al. 2016)</td>
</tr>
<tr>
<td>Solid Earth Tide</td>
<td>TIDE2000</td>
</tr>
<tr>
<td>Ocean Tide</td>
<td>EOT11A (100)</td>
</tr>
<tr>
<td>Ocean Pole Tide</td>
<td>Desai (100)</td>
</tr>
<tr>
<td>AOD Dealiasing</td>
<td>AOD1B (RL05)</td>
</tr>
<tr>
<td>Ephemeris (3rd bodies)</td>
<td>DE405</td>
</tr>
<tr>
<td>Nutation Model</td>
<td>IERS2010</td>
</tr>
<tr>
<td>Subdaily Pole Model</td>
<td>IERS2010</td>
</tr>
<tr>
<td>a priori Gravity Field</td>
<td>AIUB’s a priori Model (AIUB-GRACE03S)</td>
</tr>
<tr>
<td>Accelerometer Measurement</td>
<td>GRACE ACC1B Data</td>
</tr>
<tr>
<td><strong>Time Span</strong></td>
<td>January 2007 (1 Month)</td>
</tr>
</tbody>
</table>
Stochastic Pulses ⇔ Estimated Scaling Factors (1 Month)

<table>
<thead>
<tr>
<th>Pulse Constraints (m/sec)</th>
<th>Estimated Scale Factor (Daily in January 2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 x 10^{-8}</td>
<td>![Graph for 1 x 10^{-8}]</td>
</tr>
<tr>
<td>3 x 10^{-9}</td>
<td>![Graph for 3 x 10^{-9}]</td>
</tr>
<tr>
<td>8 x 10^{-10}</td>
<td>![Graph for 8 x 10^{-10}]</td>
</tr>
</tbody>
</table>

- Smaller constraints to control overall RMS of the stochastic pulses result in the estimated scale factors which are closer to the nominal value, 1.
Stochastic Parameters (01 January 2007)

- Four different RMS constraints for the stochastic parameters: $1 \times 10^{-8}$, $3 \times 10^{-9}$, $8 \times 10^{-10}$, $3 \times 10^{-12}$ [m/s²]
- Magnitude of the stochastic parameters (piece-wise constant accelerations) are constrained by the pre-defined constraints.
Residuals (1): by Pulse Constraints (01 January 2007)

- When the pulse constraints decreases, the residuals increases.
  ➔ The pulse constraints cannot be very small, but should be adjusted: $1 \times 10^{-9} \sim 3 \times 10^{-9} \text{ m/s}^2$ is reasonable level of the piece-wise constant accelerations.
Residuals (2): by each Direction (01 January 2007)

- Radial direction shows larger residuals than the other directions → related to the estimated scale factor in the radial direction closer to 1 than those in other directions
Conclusions

• In the Celestical Mechanice Approach to produce GRACE gravity field solutions, the magnitudes of contraints to the RMS of the stochastic pulses affect the estimated scaling factors for the accelerometer data calibration directly.

• Considering the reasonable levels of the residuals and the stochastic pulses to absorb the model deficiencies in the orbit determination, a value in the range $1 \times 10^{-9} \sim 3 \times 10^{-9}$ m/s$^2$ has to be selected for the constraints of the RMS of the stochastic parameters.

• Further improvements in the method of the estimation of the scaling factors used for the accelerometer data calibration are expected to improve at least certain coefficients of the monthly gravity field solutions in the gravity field using the Celestial Mechanics Approach.
Reference


• Thank you for your interest in this study.

This research was supported by the European Union's Horizon 2020 research and innovation program under the grant agreement No. 637010.

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To the Main Slide