The role of accelerometer data calibration within the ITSG-Grace2016 release: impact on C20 coefficients

Beate Klinger, Torsten Mayer-Gürr, Andreas Kvas, Norbert Zehentner, Matthias Ellmer and Saniya Behzadpour

Institute of Geodesy
Graz University of Technology

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Outline

1) Accelerometer data
2) Calibration approach
3) Biases & Scale factors
4) Impact on C20
5) Conclusions & Outlook
Accelerometer data

SuperSTAR accelerometer
- Three-axis electrostatic accelerometer (ONERA)
- **Two high-sensitive axes:** along-track, radial
- **One less-sensitive axis:** cross-track

Accelerometer Level-1B data:
- ACC1B data contains instrument bias and scale
- A-priori values from GRACE Technical Note TN-02 (Bettadpur, 2008)
- **April 2011:** active thermal control was switched off
- Temperature variations correlated with beta prime (β') angle variations
- **Disturbance effects:** thruster firings, heater switches, twangs, magnetic torquer induced accelerations, …
  (Flury et al., 2008; Peterseim et al. 2012)
Calibration approach

Accelerometer biases & scale factors:

- Two-step approach: a-priori calibration for data screening
- Calibration equation: \( \mathbf{a}_{\text{cal}} = \mathbf{S} \mathbf{a}_{\text{obs}} + \mathbf{b} \)

\[
\mathbf{S} = \begin{bmatrix}
    s_x & \alpha + \zeta & \beta - \epsilon \\
    \alpha - \zeta & s_y & \gamma + \delta \\
    \beta + \epsilon & \gamma - \delta & s_z
\end{bmatrix}
\]

- Main-diagonal elements
- Shear parameter
- Rotation parameter

1) Biases:
- Estimation: once per day
- Parameterization: uniform cubic basis splines (UCBS), with a 6h knot interval

2) Scale factors:
- Estimation: once per day
- Parameterization: fully-populated scale factor matrix
- Off-diagonal elements: non-orthogonality of accelerometer axes (cross-talk), misalignment between SRF and AF
Calibration approach

Accelerometer biases & scale factors:

- Two-step approach: a-priori calibration for data screening
- Calibration equation: $\mathbf{a}_{\text{cal}} = \mathbf{S} \mathbf{a}_{\text{obs}} + \mathbf{b}$

1st step calibration – Data pre-processing:

- Calibration parameters: biases and scale factors
- Modeled non-gravitational accelerations are used as reference to estimate calibration parameters
- Enables data screening

2nd step calibration – Gravity field recovery:

- Calibration parameters: biases and scale factors
- Re-estimation of calibration parameters

The same parameterization is used for both steps!
Bias

- **Bias = offset + drift**
- **Temperature-induced bias drifts:**
  - Related to occasional disabling of heaters (< 2011-04)
  - Related to orbital configuration w.r.t the Sun (> 2011-04)
Bias drifts

- After thermal control switch-off: bias drifts related to **orbital configuration**
- Heating and cooling of the satellite: cross-track axis shows strongest variations

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**Accelerations - ACC1B**

**Accelerations - calibrated**

[Graphs showing temperature and cross-track accelerations over date (DOY)].
Bias drifts

- After thermal control switch-off: bias drifts related to **orbital configuration**
- Heating and cooling of the satellite: cross-track axis shows strongest variations
- **Temperature changes highly correlated with beta prime (β') angle variations**

![Temperature & Beta Prime Angle Graph](image-url)
Scale factors

- **Main diagonal elements:**
  - Scale factors: along-track ($s_x$), cross-track ($s_y$), radial ($s_z$)

- **Non-constant behavior**
- **High sensitive axes better estimable and less scattered**
Scale factors

- Off-diagonal elements: \( xy, xz, yz \)
- Shear parameter: \( \alpha, \beta, \gamma \)
- Rotational parameter: \( \zeta, \varepsilon, \delta \)

- Shear and rotational parameters highly correlated
Temperature-dependency

April 2011 – present:

- Scale factors highly correlated with temperature variations (> 2011-04)
- Temperature variations are absorbed by calibration parameters and map into time-series

2011-04: Thermal control stopped
Atmospheric density (DTM2013)

- Scale factors better estimable for periods with higher atmospheric densities (i.e. larger non-gravitational signal)
- Density variations depend on solar activity, geomagnetic activity and altitude
Beta prime (β') angle

- **Shear parameter**: mutual influence among the cross-track and radial axes, due to non-orthogonality of AF and SRF
- 161-day periodic signal
Altitude

- **Interference from other axis components:** magnitude dependent on magnitude of the actual non-gravitational accelerations

- Misalignment errors are more significant for lower altitudes where larger atmospheric drag is present
Impact on C20 coefficients

- Fully-populated scale factor matrix: offset w.r.t SLR is reduced (2008-2014)
Impact on C20 coefficients

- **Fully-populated scale factor matrix**: offset w.r.t SLR is reduced (2008-2014)
- Differences increase at the beginning and end of GRACE time-series
Conclusions & Outlook

- GRACE accelerometers are extremely sensitive to temperature variations
- Temperature-induced variations of calibration parameters (biases & scale factors)
- Fully-populated scale factor matrix significantly improves estimates of C20 coefficients
- ACC parameterization also influences:
  - Other low degree coefficients
  - Overall accuracy of monthly gravity field solutions
- Further analysis: ideal parametrization of calibration equation
  - Model not “physically correct”
  - Parameters are likely to absorb other spurious signals

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Degree amplitudes

- **ITSG-Grace2016 (prelim):** main-diagonal elements only
- **ITSG-Grace2016:** fully-populated scale factor matrix
Modeled non-conservative accelerations