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

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Introduction

Both GRACE (Gravity Recovery and Interior Laboratory) satellites are equipped with a three-axis capacitive accelerometer, measuring the non-gravitational forces acting on the spacecraft. In order to make use of the uncalibrated Level-1B accelerometer data (ACC1B) during gravity field recovery, bias and scale parameters have to be estimated.
We present a two-step approach used for ACC1B data calibration within the ITSG-Grace2016 release and analyze its impact on the recovered gravity field solutions, especially on C20 coefficients.

SuperSTAR accelerometer

- Three-axis capacitive accelerometer manufactured by ONERA [6]
- Measures the **non-conservative accelerations** due to atmospheric drag, solar radiation pressure and Earth albedo

Noise characteristics:
- Two high sensitive axes: along-track (X_{SRF}), radial (Z_{SRF})
- One less-sensitive axis: cross-track (Y_{SRF})

Disturbance effects:
- Thruster firings
- Heater switches & Temperature variations
- Magnetic torquer induced accelerations [1, 4]
- Others

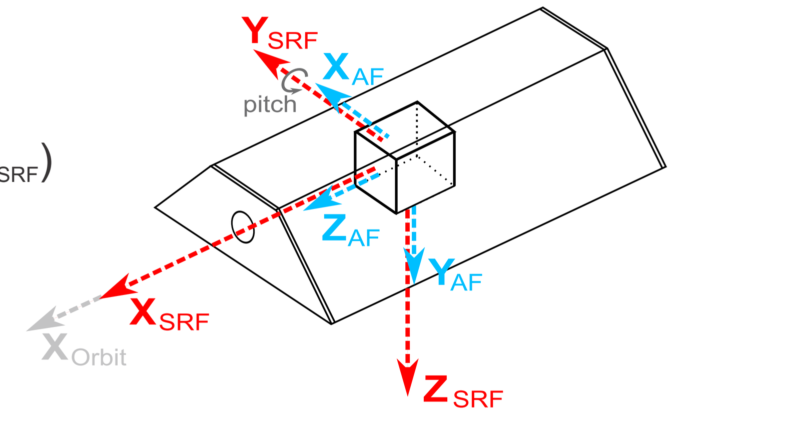


Fig. 1: Accommodation of the Accelerometer Frame (AF) and Science Reference Frame (SRF) within the GRACE spacecraft.

Modeled non-conservative accelerations

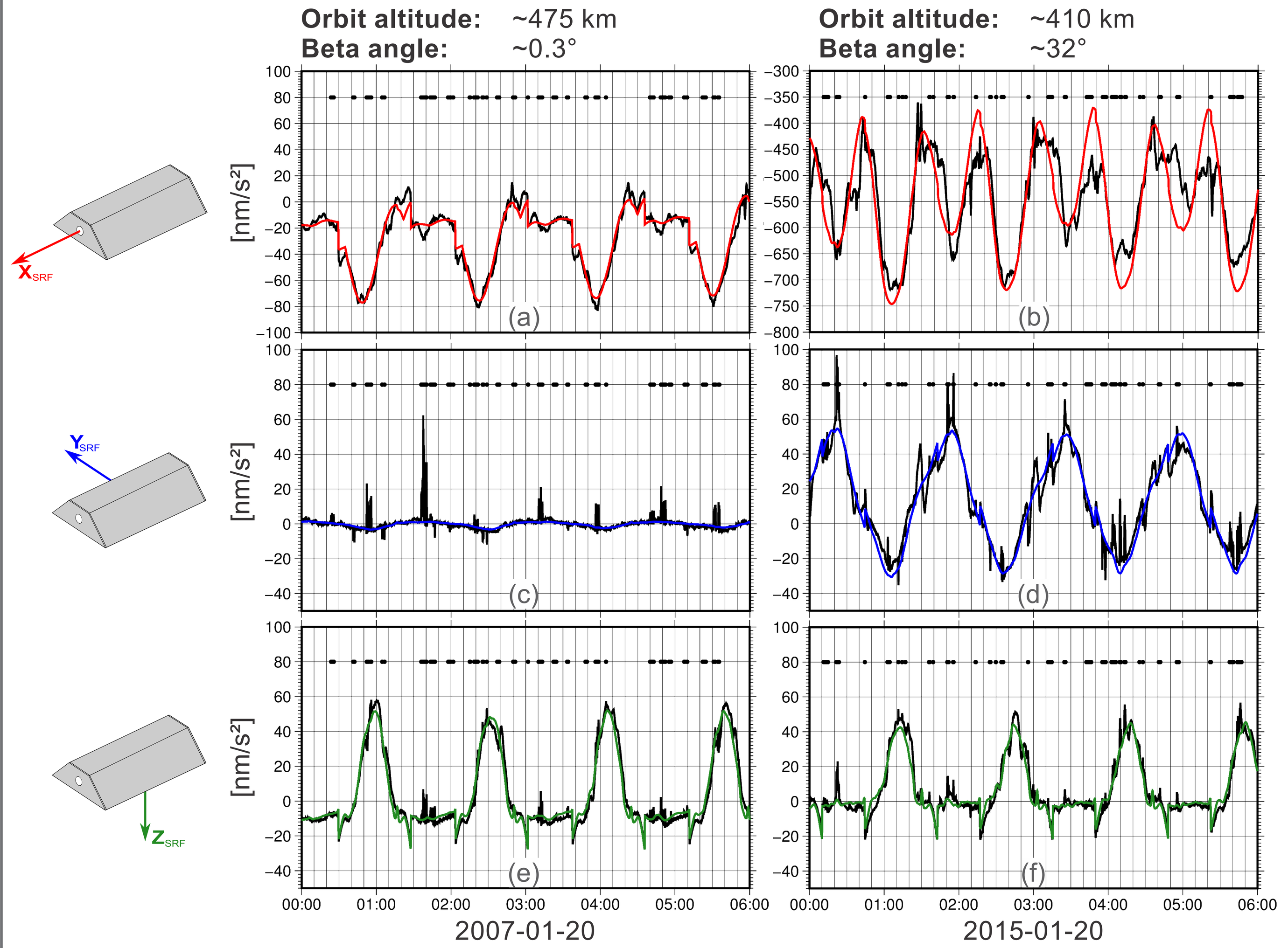


Fig. 2: Modeled non-conservative accelerations (color) and ACC1B data (black) in along-track (a, b), cross-track (c, d) and radial direction (e, f). Here, the ACC1B data is bias corrected. The non-conservative accelerations for GRACE-A are shown for a 6h segment on 2007-01-20 and 2015-01-20. The scaling for (a) and (b) is different.

Details on the modeling of the non-conservative forces acting on GRACE are given in [2].

Calibration approach - Estimation of biases and scale factors

- Two-step approach
- **Calibration equation:**

$$\mathbf{a}_{\text{cal}} = \mathbf{S}\,\mathbf{a}_{\text{obs}} + \mathbf{b}$$

$$\text{with} \quad \mathbf{S} = \begin{bmatrix} s_x & \alpha+\zeta & \beta-\epsilon \\ \alpha-\zeta & s_y & \gamma+\delta \\ \beta+\epsilon & \gamma-\delta & s_z \end{bmatrix}$$

- **Main diagonal elements** (scale)
- **Shear parameter** (non-orthogonality of ACC axes)
- **Rotational parameter** (misalignment between SRF & AF)

(1) Biases (b):
- Estimation: Once per day
- Parameterization: Uniform Cubic Basis Splines (UCBS), with a 6h knot interval

(2) Scale factors (S):
- Estimation: Once per day
- Parameterization: Fully-populated scale factor matrix

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

Temperature induced Bias-drifts

- Related to occasional disabling of heaters (< 2011-04)
- Related to orbital configuration w.r.t the Sun (β' angle variations) (> 2011-04)
- Cross-track axis shows strongest variations due to heating and cooling of the satellite

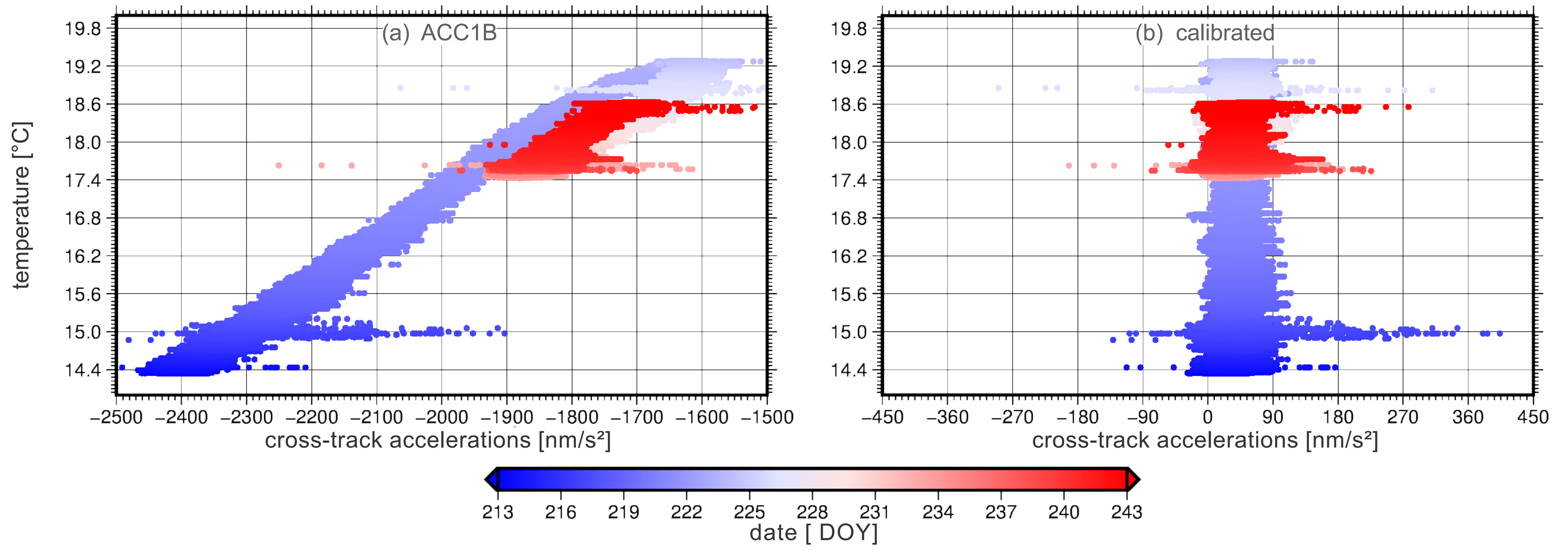
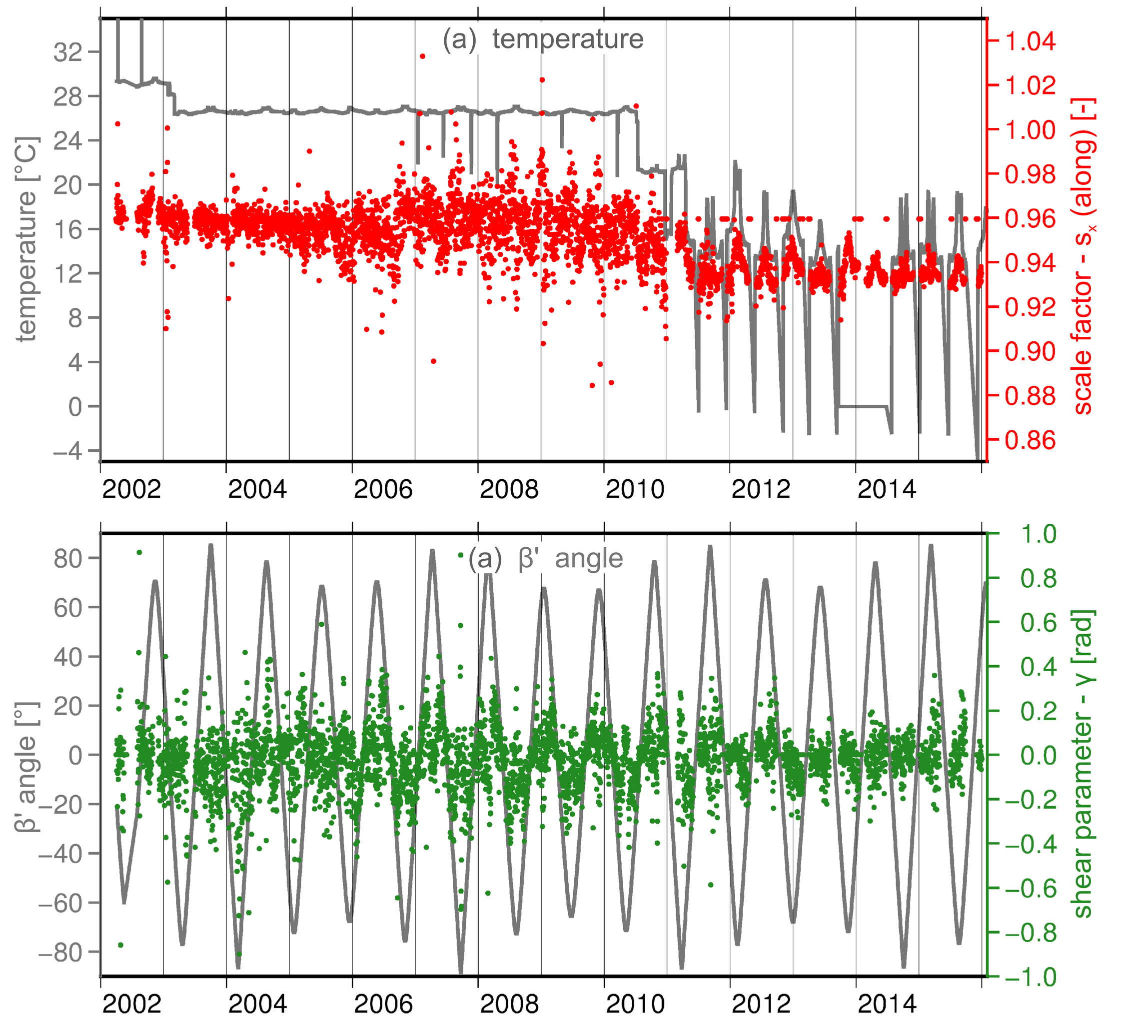


Fig. 3: Comparison of original ACC1B data (a) and calibrated ACC data (b) with temperature measurements (AHK1B - core-temperature) of GRACE-A for one month (2015-07).

Evolution of scale factors



Estimated scale factors:
- Non-unit main diagonal elements
- Non-zero off-diagonal elements (shear and rotational parameter)
- All elements show temporal variability

Details on the individual elements of the scale factor matrix can be found in [2].

Fig. 4: Upper panel (a): Temporal evolution of estimated scale factor s_x in along-track direction compared to the accelerometer core-temperature (AHK1B). **Lower panel (b):** Temporal evolution of estimated shear parameter γ and the corresponding β' angle variations. The shear parameter γ represents the cross-talk among the cross-track and radial axis due to the non-orthogonality of the accelerometer axes. Both figures show the estimated parameters for GRACE-A from 2002 to 2016.

Impact on C20 coefficients

ITSG-Grace2016 [3]:
- 161-day periodic signal reduced
- Better agreement with independent SLR solution [5]

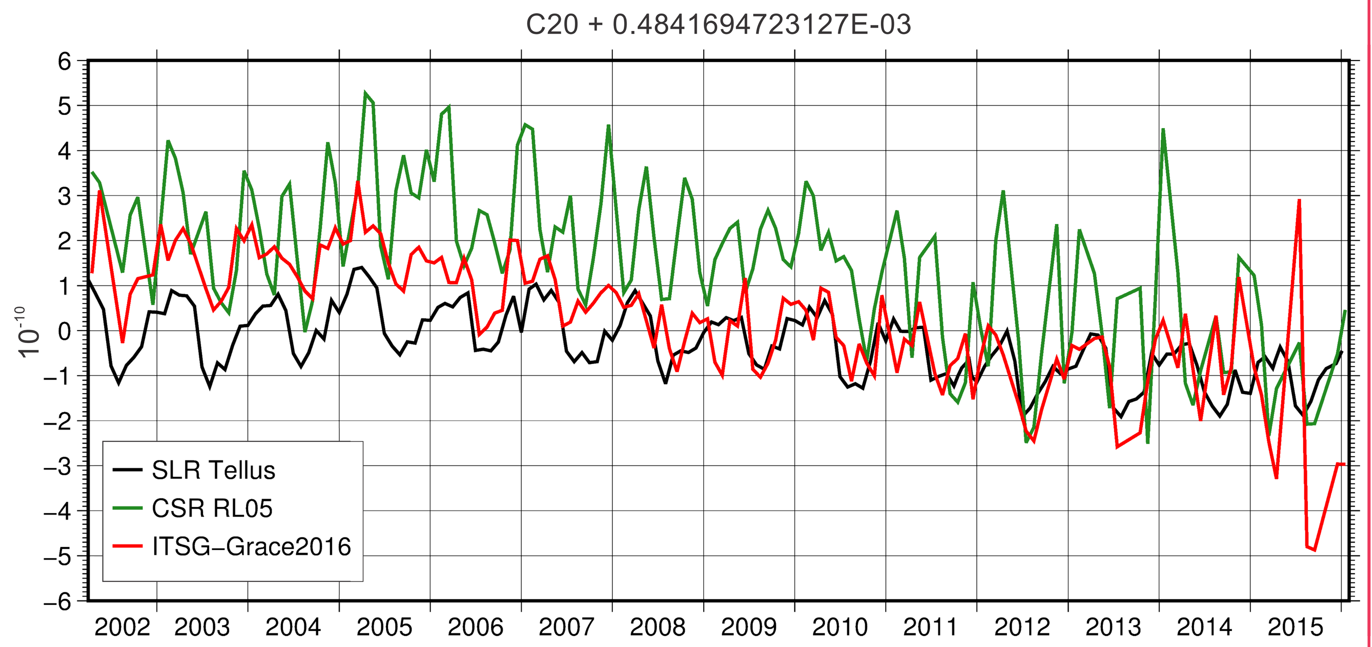


Fig. 5: Comparison of C20 estimates from GRACE-only monthly gravity field solutions (CSR RL05, ITSG-Grace2016) and from SLR analysis (SLR Tellus).

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 improved C20 estimates
- ACC parameterization improved overall accuracy of gravity field solutions

The proposed calibration approach aims at improving the gravity field recovery and does not guarantee a physically correct model. Hence, some further investigations w.r.t the ideal parameterization are needed.

MORE DETAILS ON THE CALIBRATION APPROACH CAN BE FOUND IN KLINGER AND MAYER-GÜRR (2016) [2]

Acknowledgements

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