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

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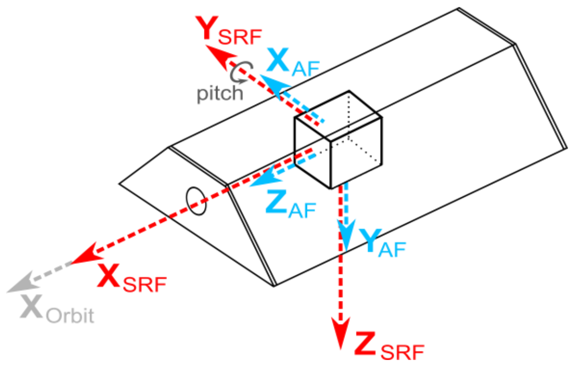
Outline

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

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

- Main-diagonal elements
- 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:

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- **Main-diagonal elements**
- **Shear parameter**
- **Rotation parameter**

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:

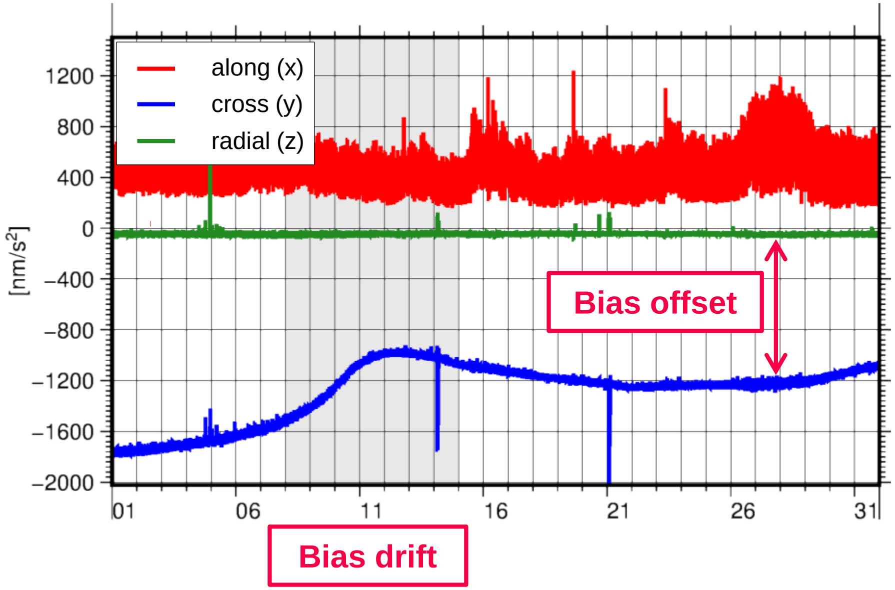
- Calibration parameters: biases and scale factors
- Re-estimation of calibration parameters

The same parameterization is used for both steps!

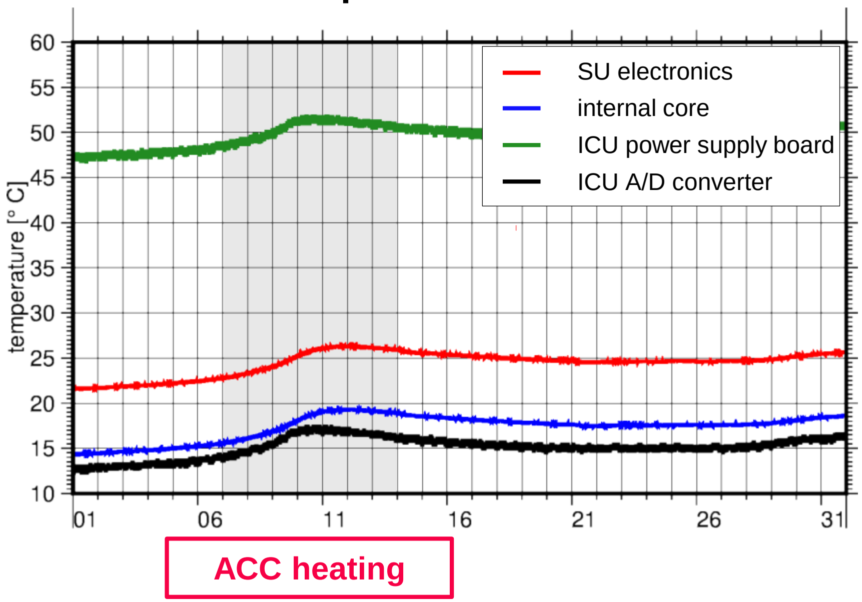
Bias

- **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)

Accelerations - ACC1B



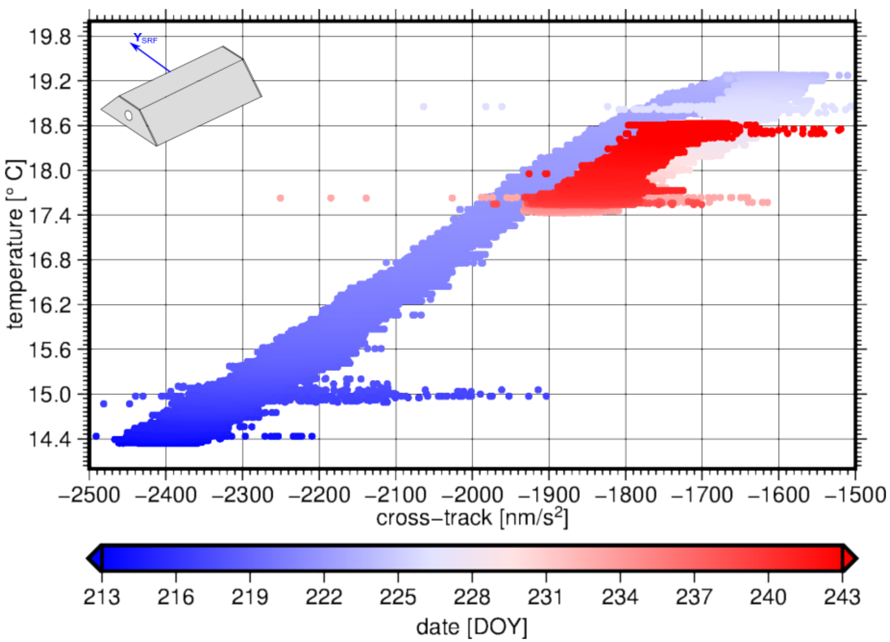
Temperature - AHK1B



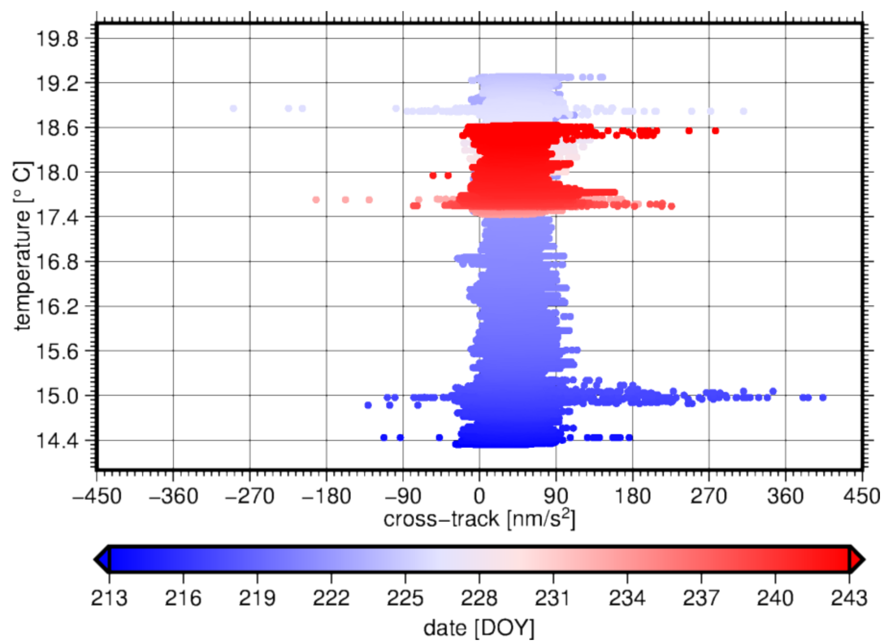
Bias drifts

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

Accelerations - ACC1B



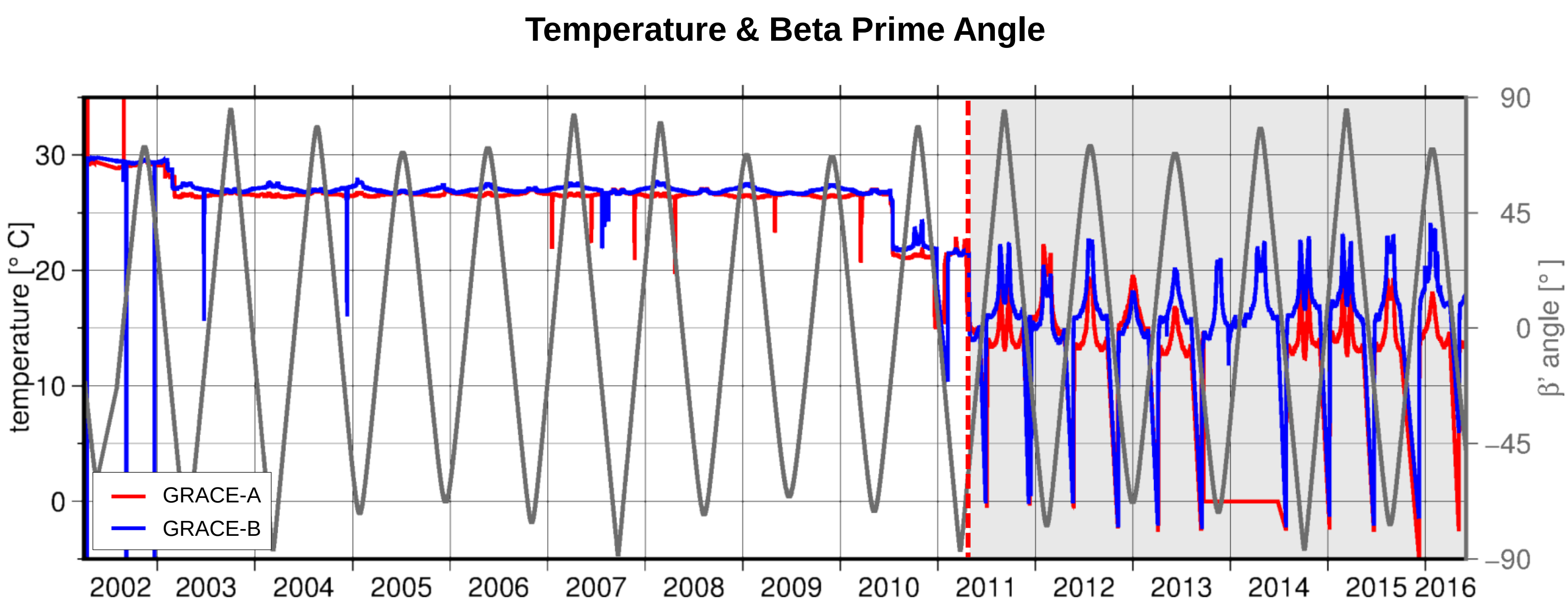
Accelerations - calibrated



Bias drifts

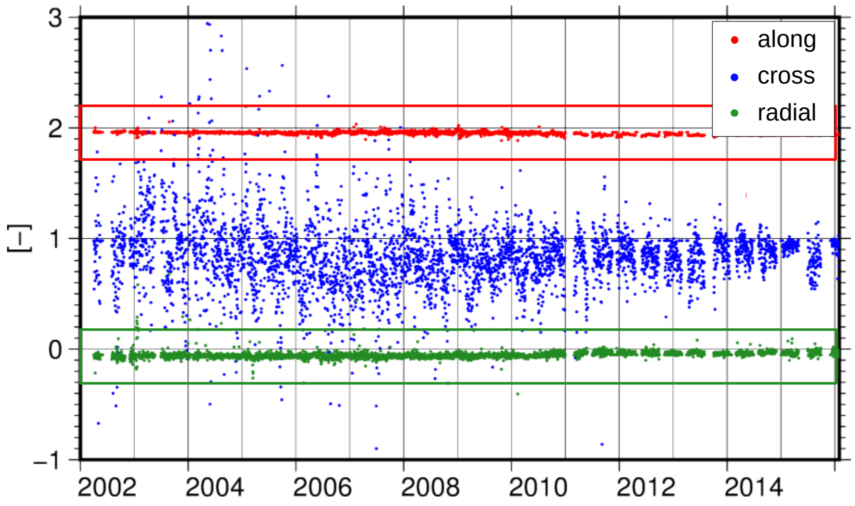
- After thermal control switch-off: bias drifts related to **orbital configuration**
- Heating and cooling of the satellite: cross-track axis shows strongest variations

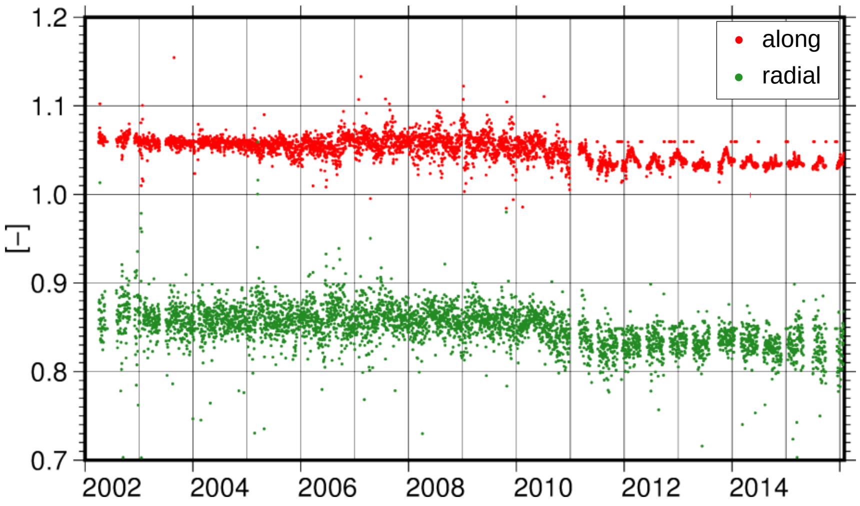
- **Temperature changes highly correlated with beta prime (β') angle variations**



Scale factors

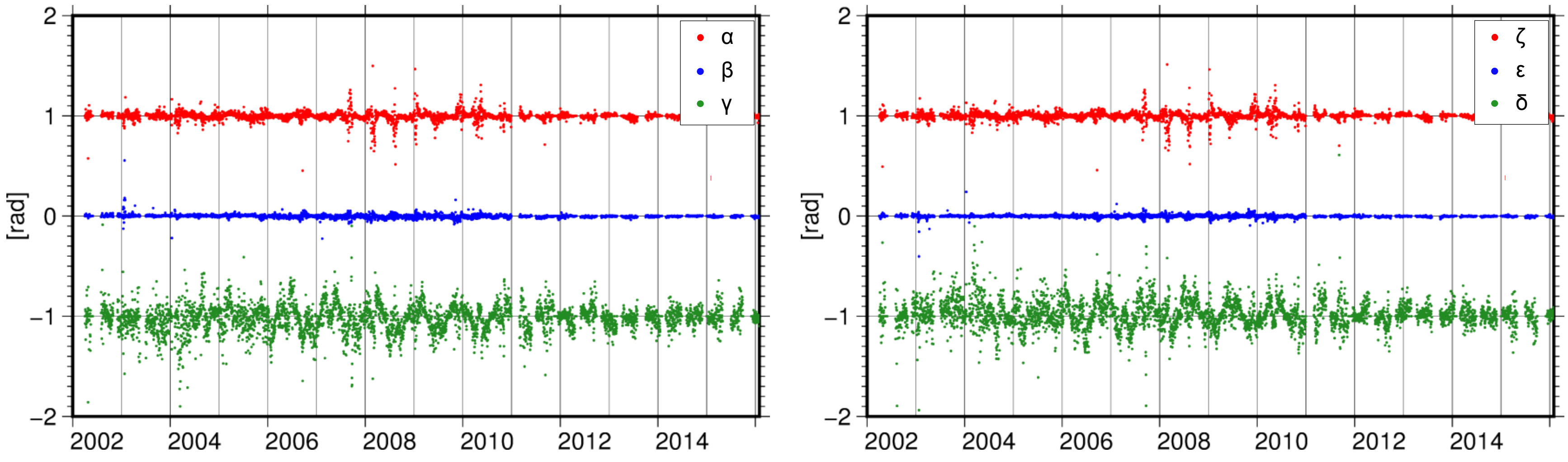
- **Main diagonal elements:**
  - Scale factors: along-track (s_x), cross-track (s_y), radial (s_z)
- Non-constant behavior
- High sensitive axes better estimable and less scattered





Scale factors

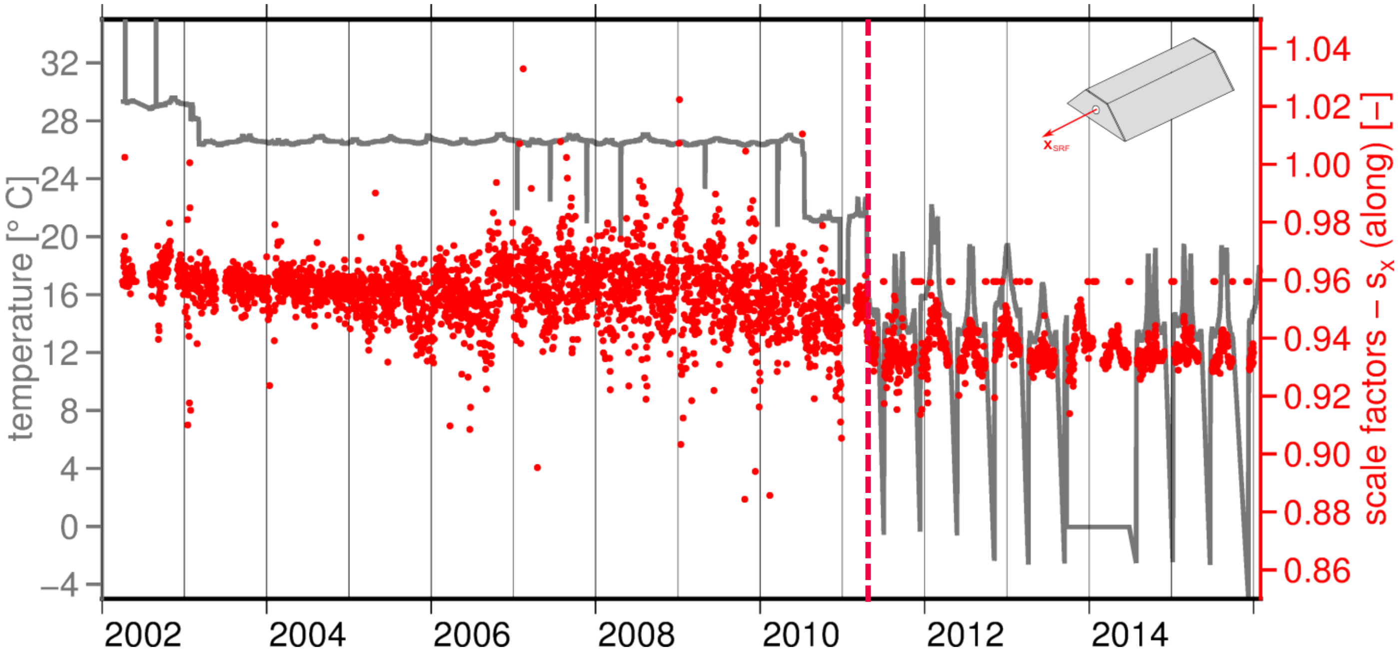
- **Off-diagonal elements** **xy**, **xz**, **yz**
  - Shear parameter: α, β, γ
  - Rotational parameter: ζ, ε, δ
- Shear and rotational parameters highly correlated



Temperature-dependency

April 2011 – present:

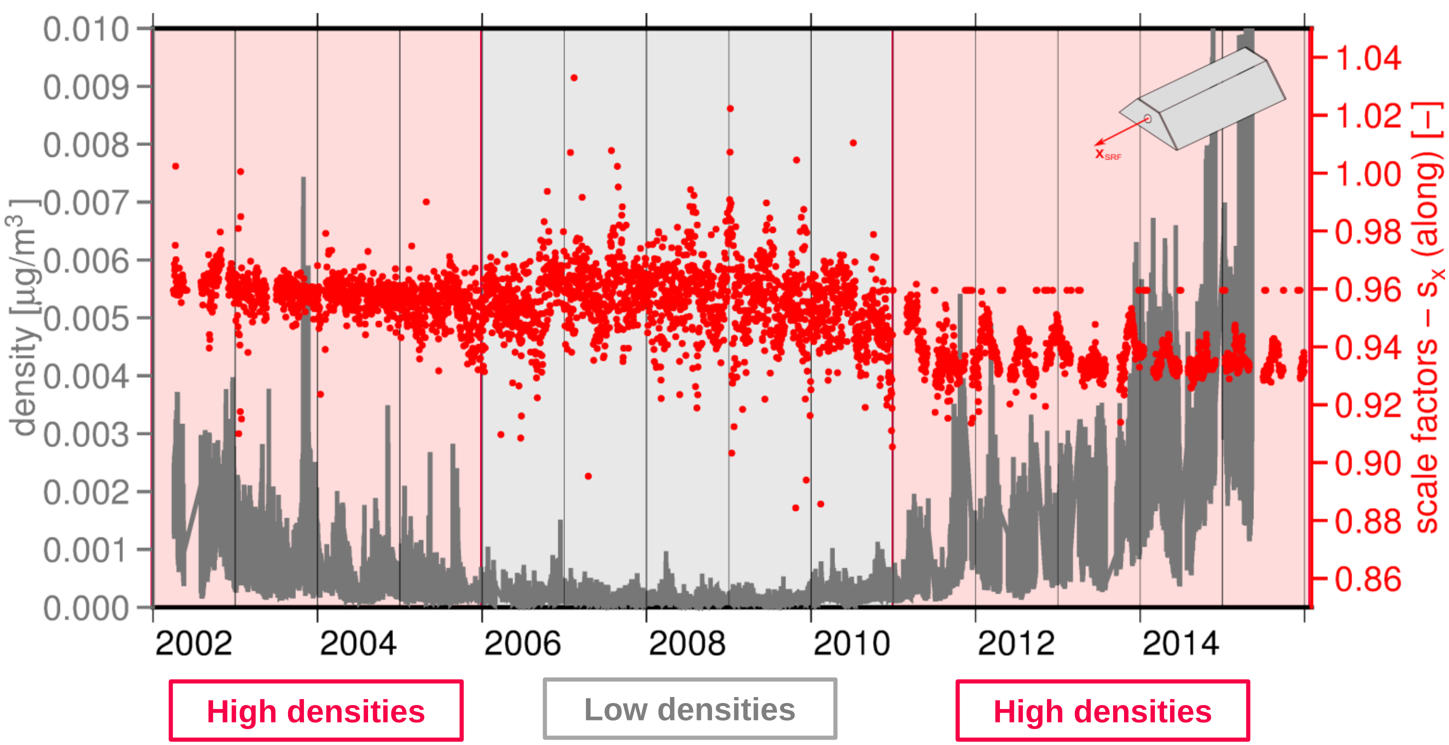
- Scale factors highly correlated with temperature variations (> 2011-04)
- Temperature variations are absorbed by calibration parameters and map into time-series



2011-04:
Thermal control stopped

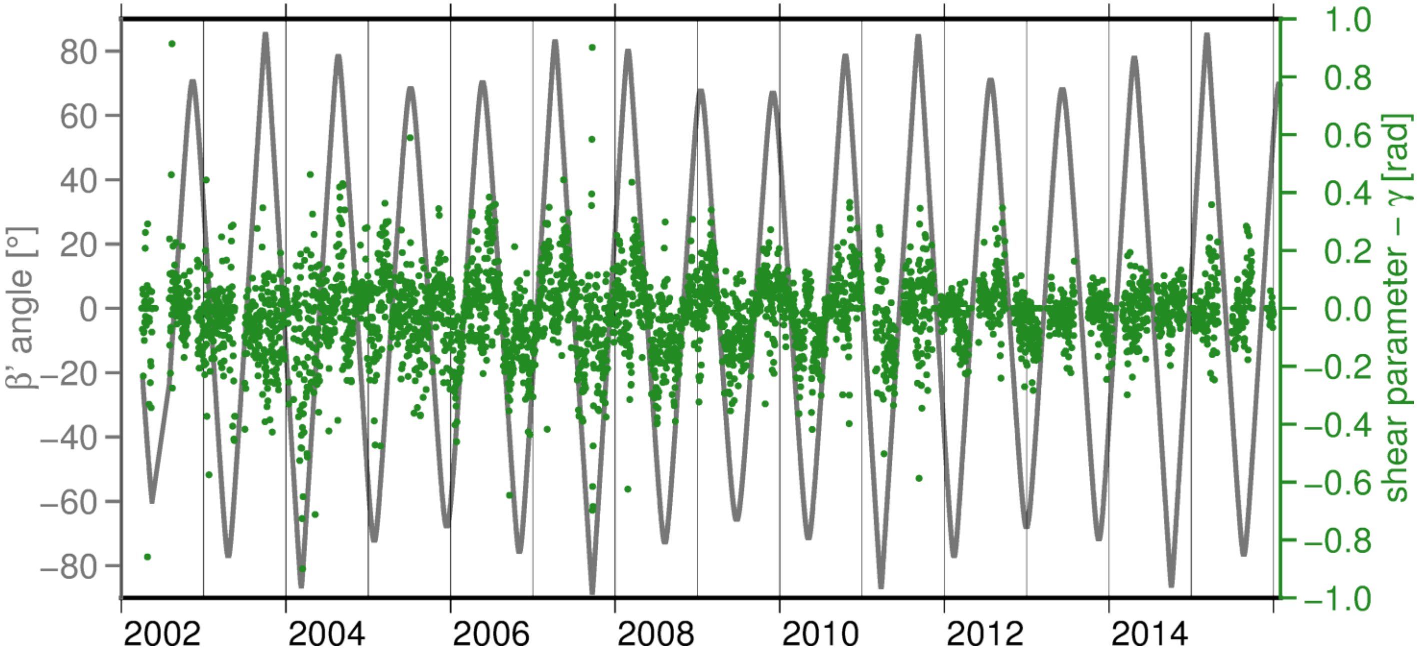
Atmospheric density (DTM2013)

- 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



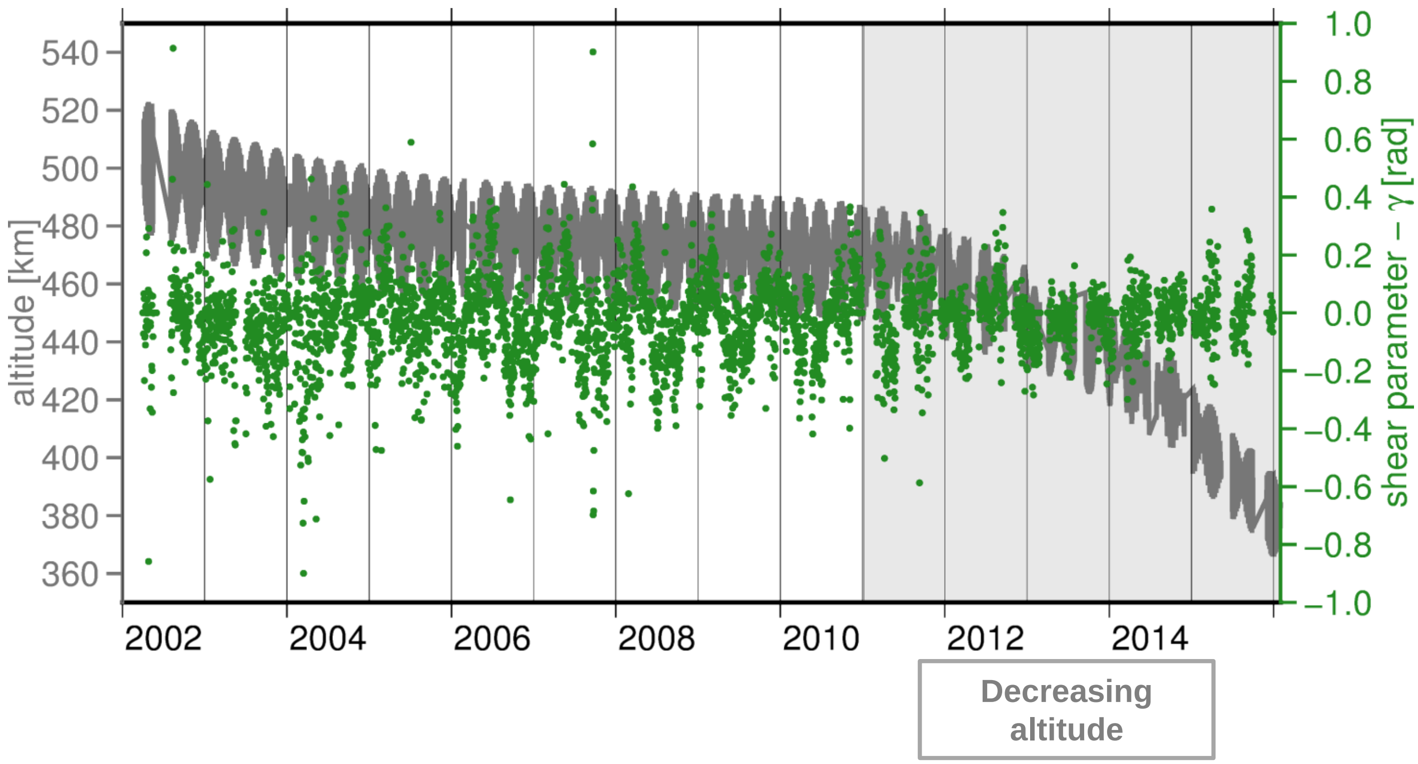
Beta prime (β') angle

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



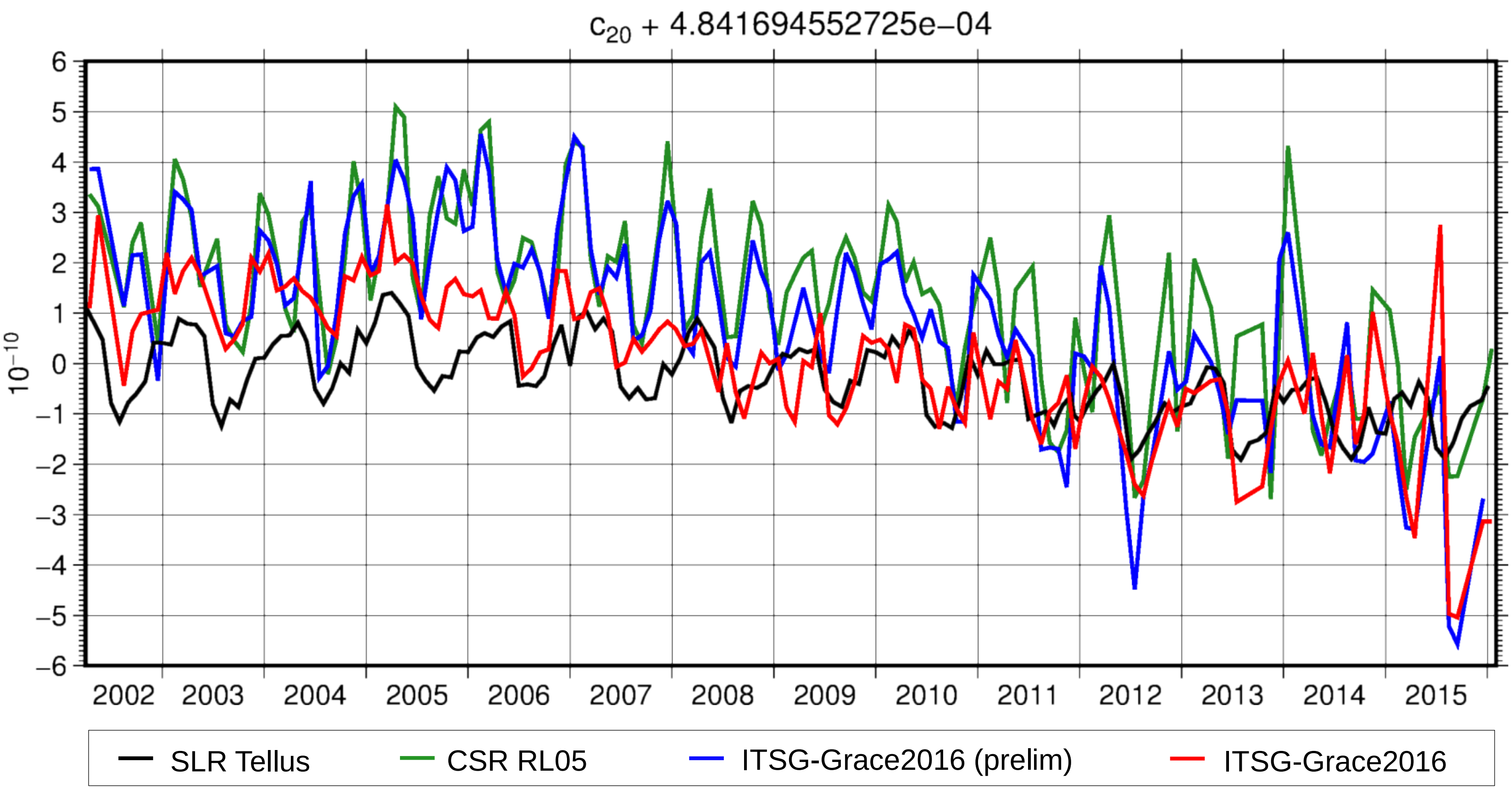
Altitude

- **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



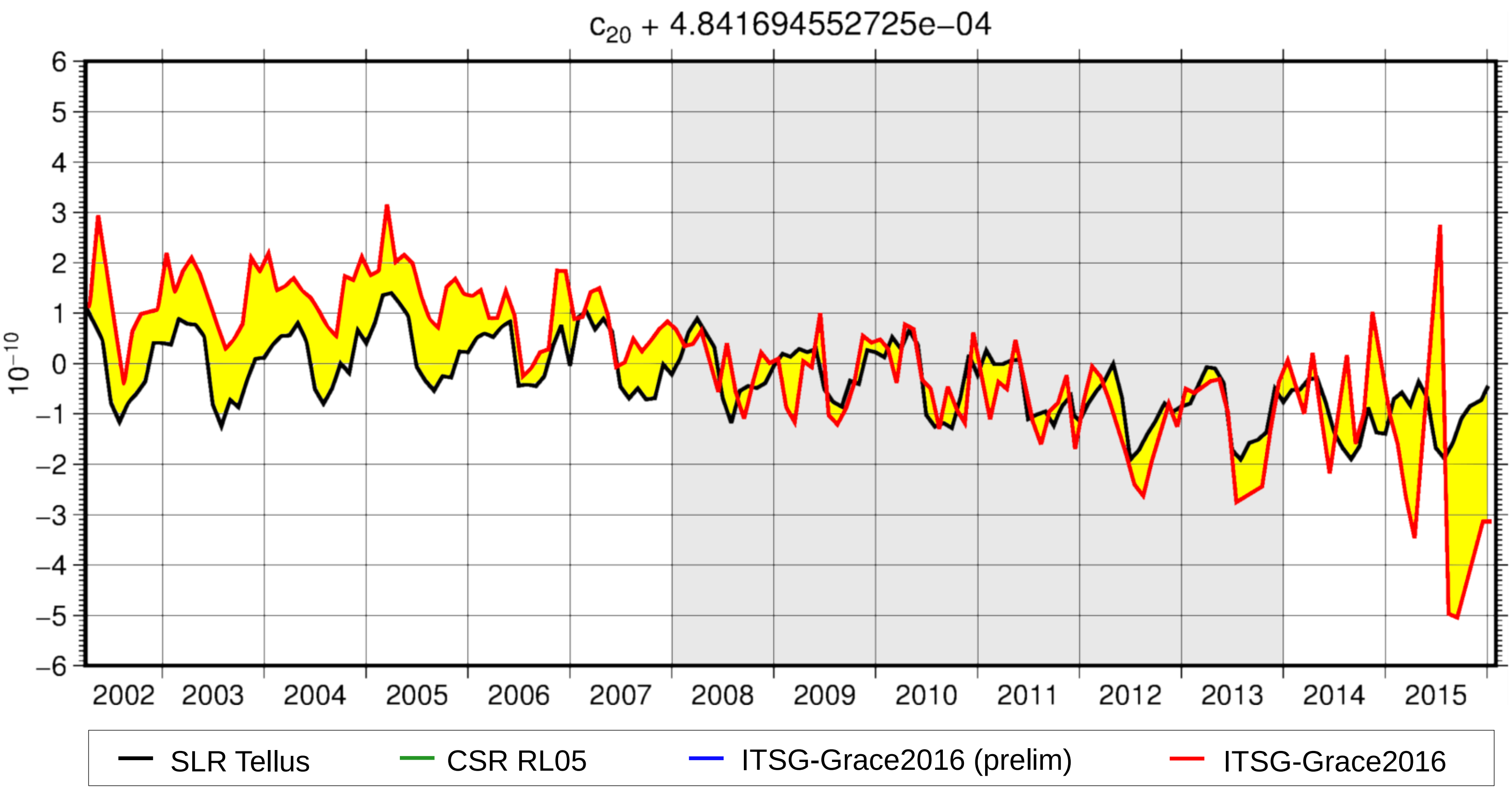
Impact on C20 coefficients

- **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



Klinger et al.

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

- **Article:** Klinger, B., Mayer-Gürr, T., 2016. The role of accelerometer data calibration within GRACE gravity field recovery: Results from ITSG-Grace2016. Adv. Space Res. 58, 1597-1609. http://dx.doi.org/10.1016/j.asr.2016.08.007

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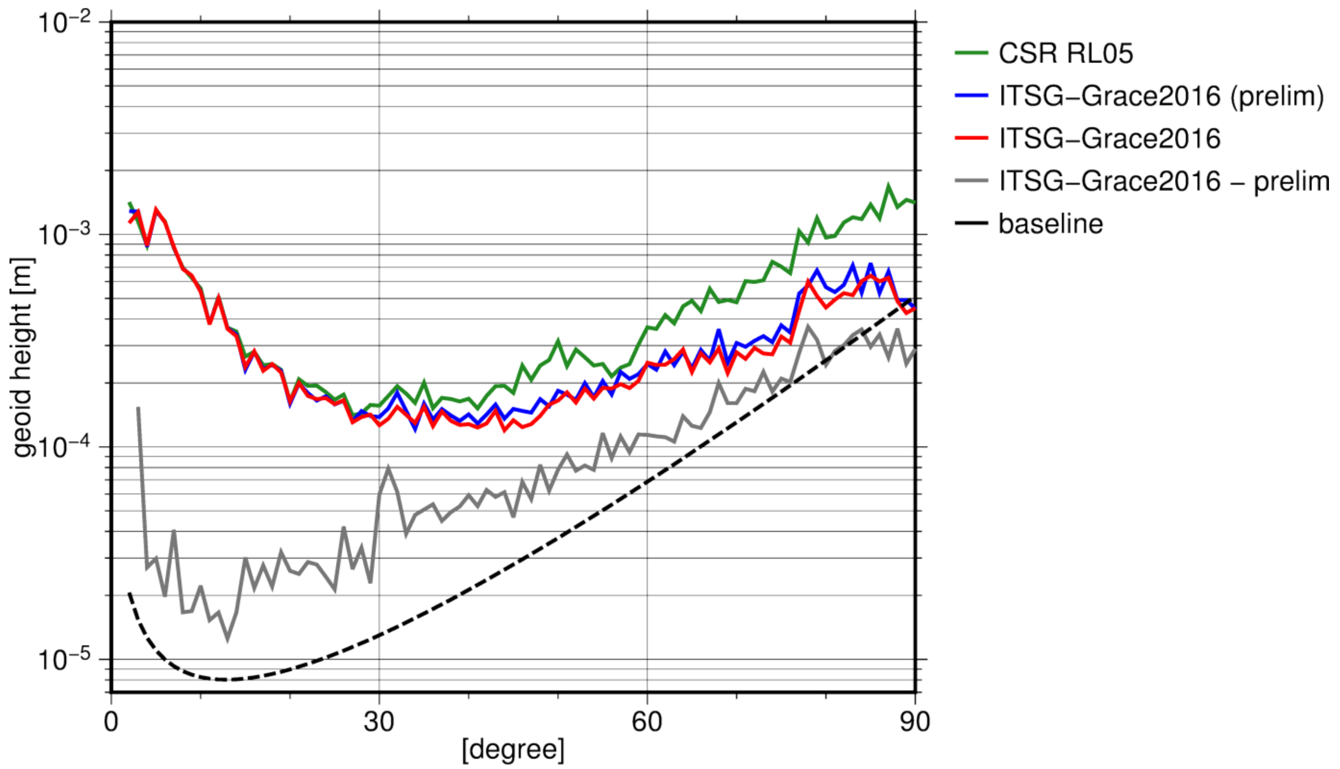
Degree amplitudes

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



Modeled non-conservative accelerations