Title: **Improved processing tools at TUG**

Presenter: BK

Affiliation: TUG

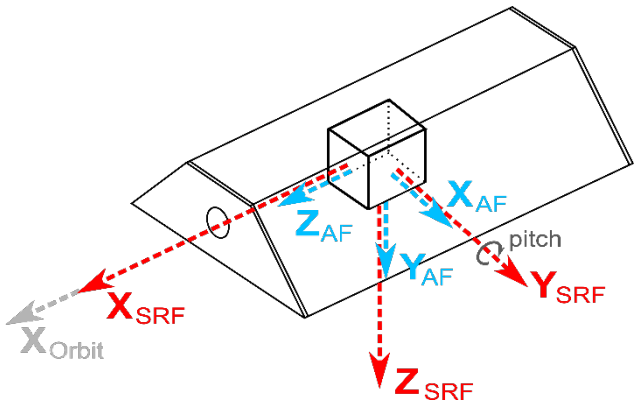
EGSIEM Meeting Potsdam,
02.06.2016 - 03.06.2016

Accelerometer calibration

SuperSTAR accelerometer

Error sources:

- **Instrument bias & scale**
- **Thermal variations**
- **Misalignment between SRF and AF**
- **Non-orthogonality of accelerometer axes**
- Noise
- Center of mass offset
- Attitude determination errors
- …



⇒ Sensor errors and satellite-induced disturbances (activation and de-activation of heaters, thermal control)

Accelerometer calibration

Accelerometer biases & scale factors:

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

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

- Main-diagonal elements
- Shear parameter
- Rotational parameter

(1) Bias:

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

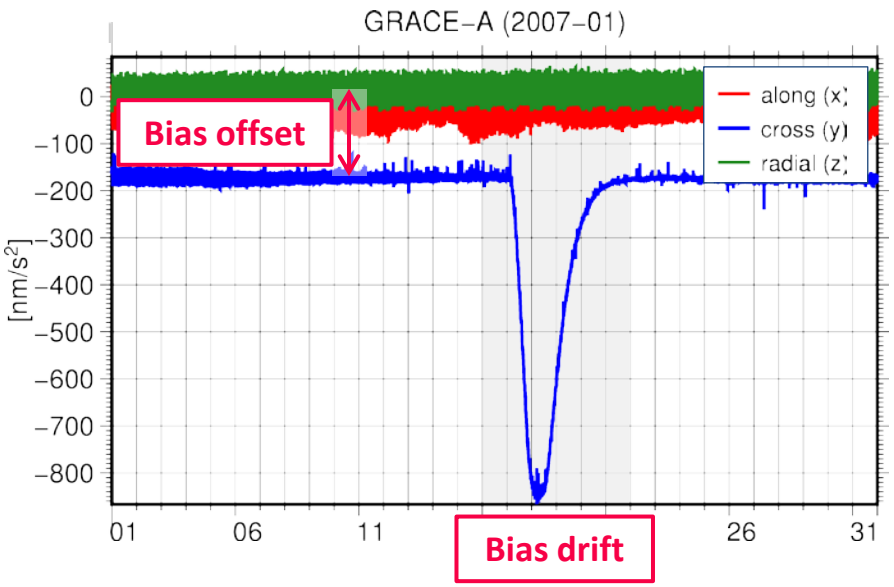
(2) Scale factors:

- 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

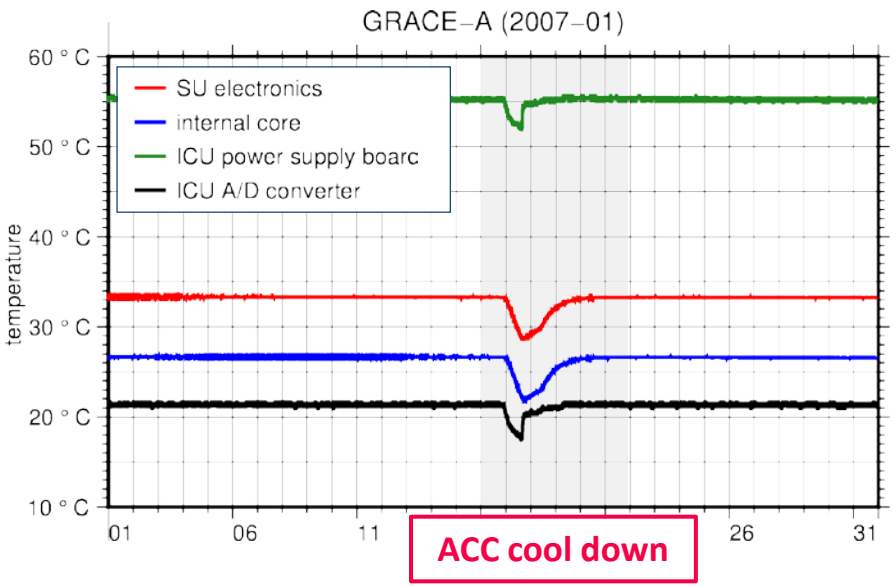
Accelerometer calibration

- Temperature-dependent behavior (biases & scale factors)
- Parameterization significantly affects C20 coefficients

Accelerations - ACC1B
(calibrated according to TN-02)



Temperature - AHK1B



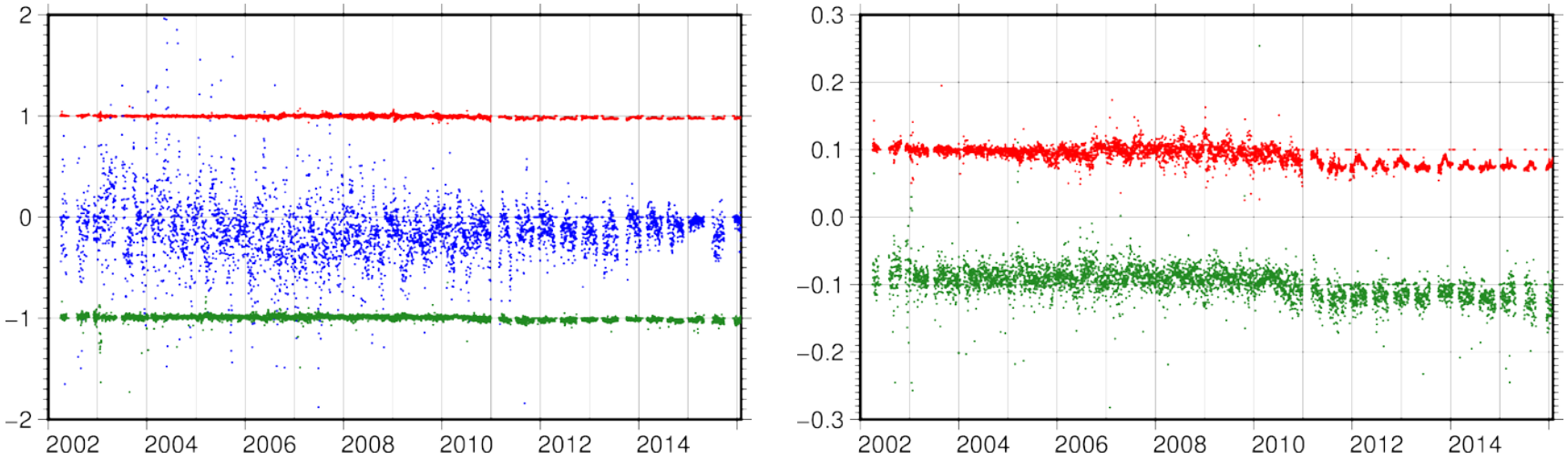
Scale factor matrix

Main diagonal elements:

- Scale factors: along (x), cross-track (y), radial (z)

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

Scale factors (GRACE-A)



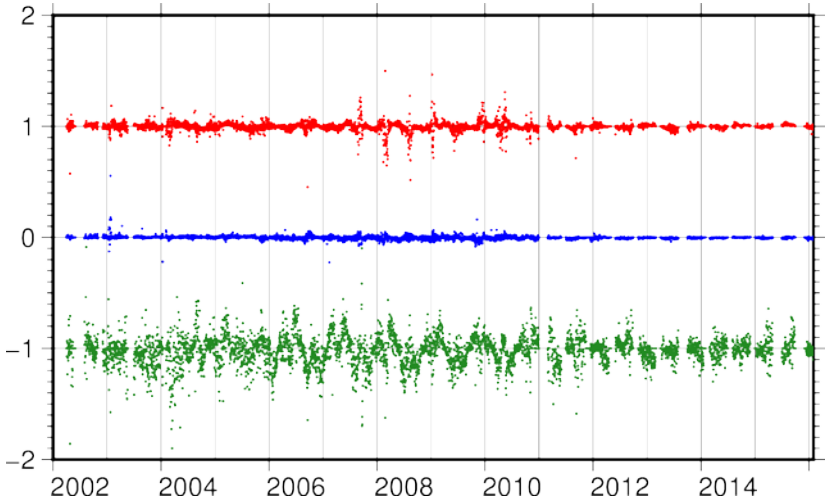
Scale factor matrix

Off-diagonal elements: xy, xz, yz

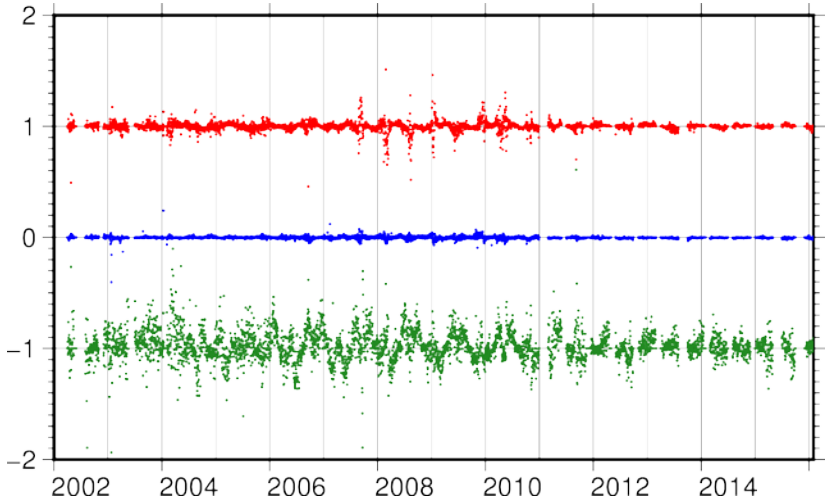
- Shear parameter: α, β, γ
- Rotational parameter: ζ, ε, δ

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

Shear parameter (GRACE-A)



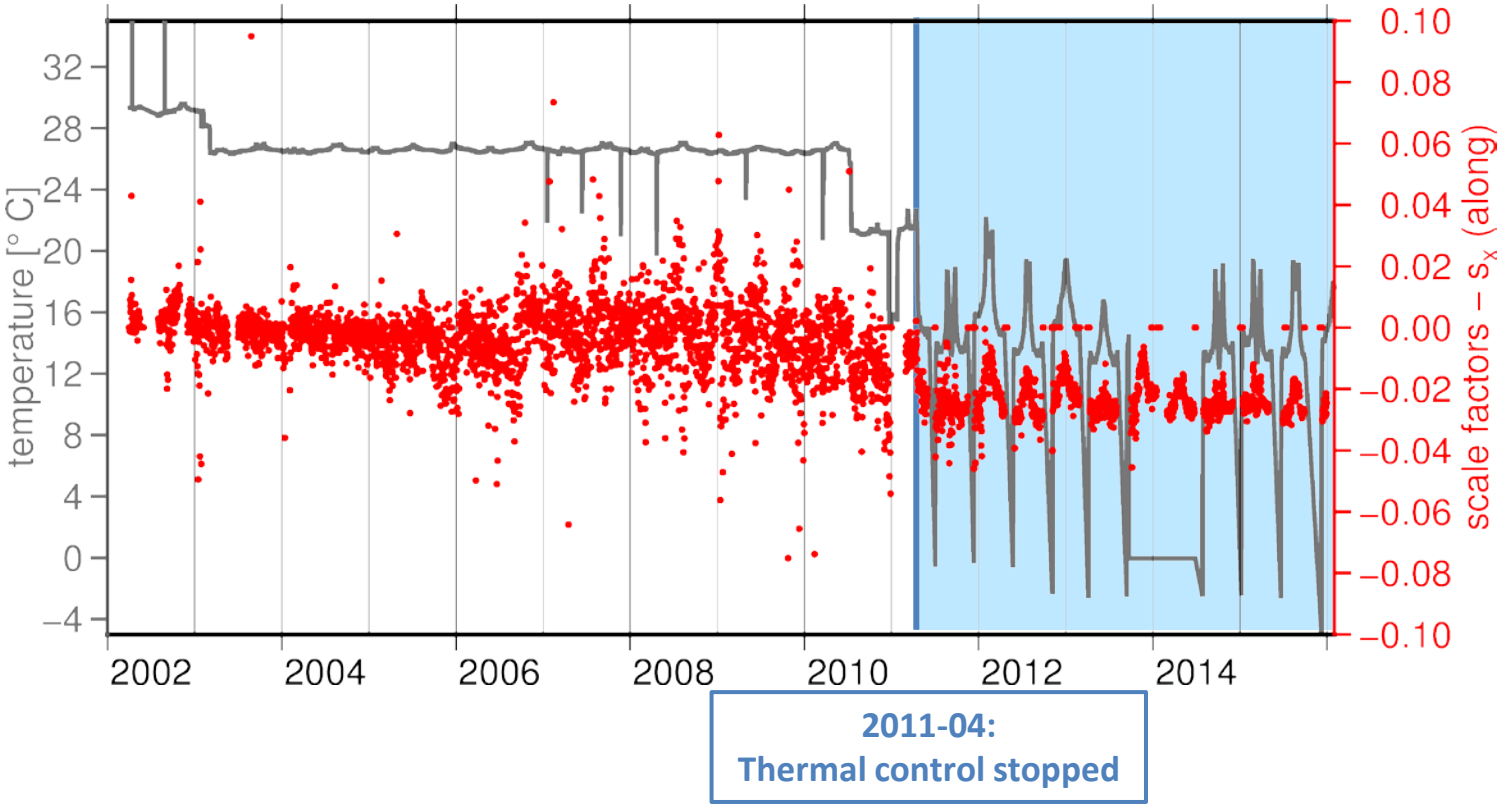
Rotational parameter (GRACE-A)



Temperature-dependency

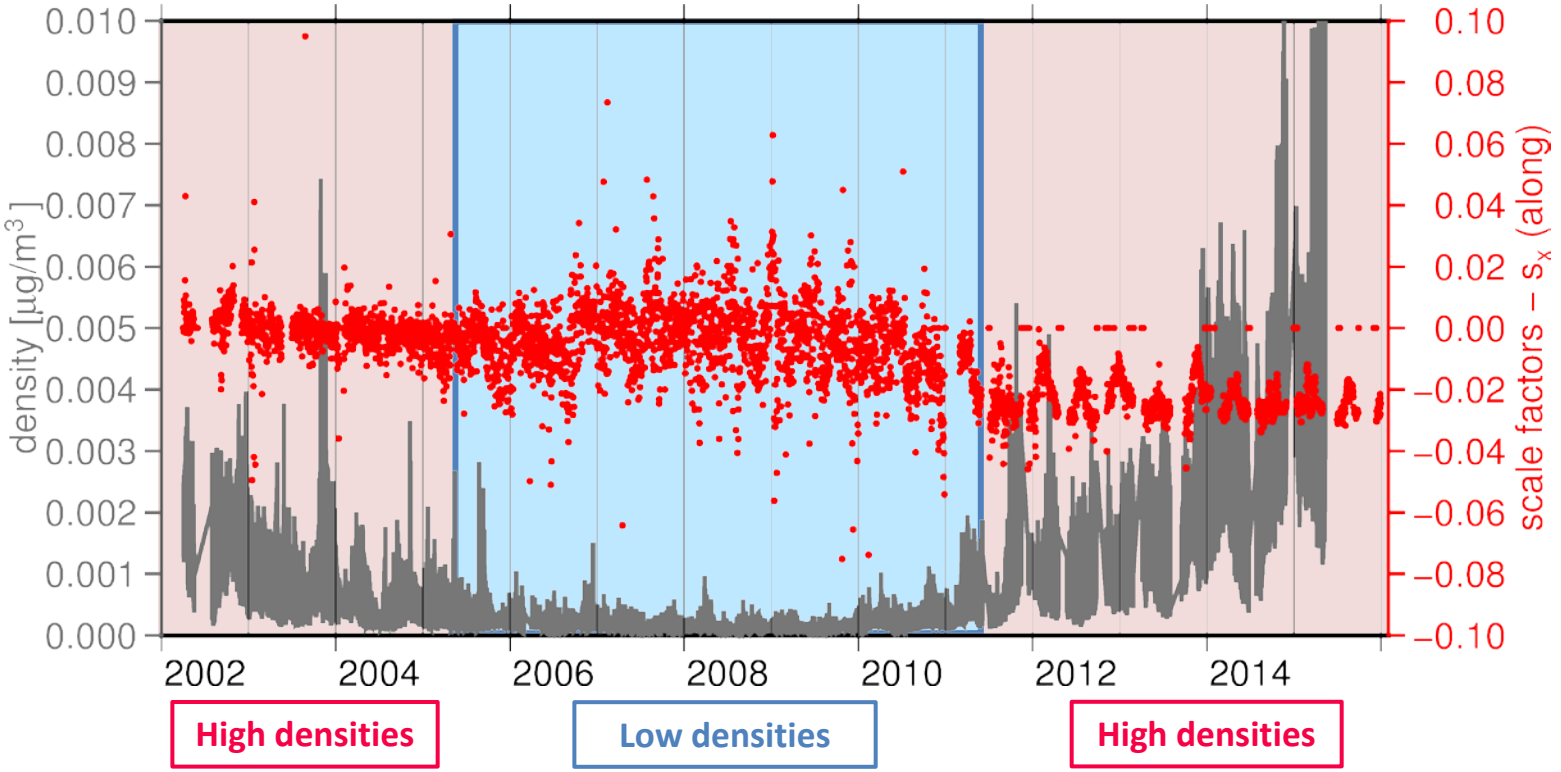
April 2011 - present:

- Scale factors highly correlated with temperature variations



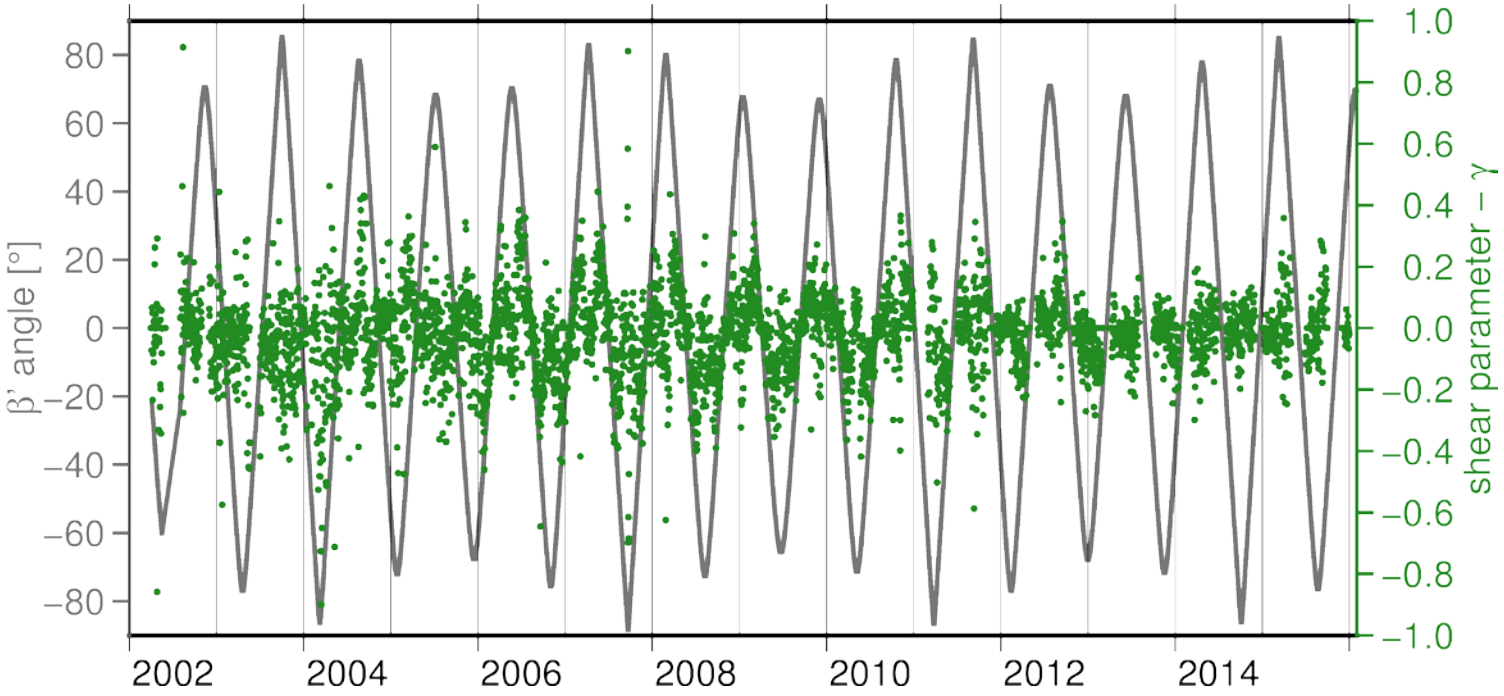
Atmospheric density (DTM2013)

- Scale factors better estimable for periods with higher atmospheric densities (non-gravitational signal)
- Variations depend on solar activity, geomagnetic activity and altitude



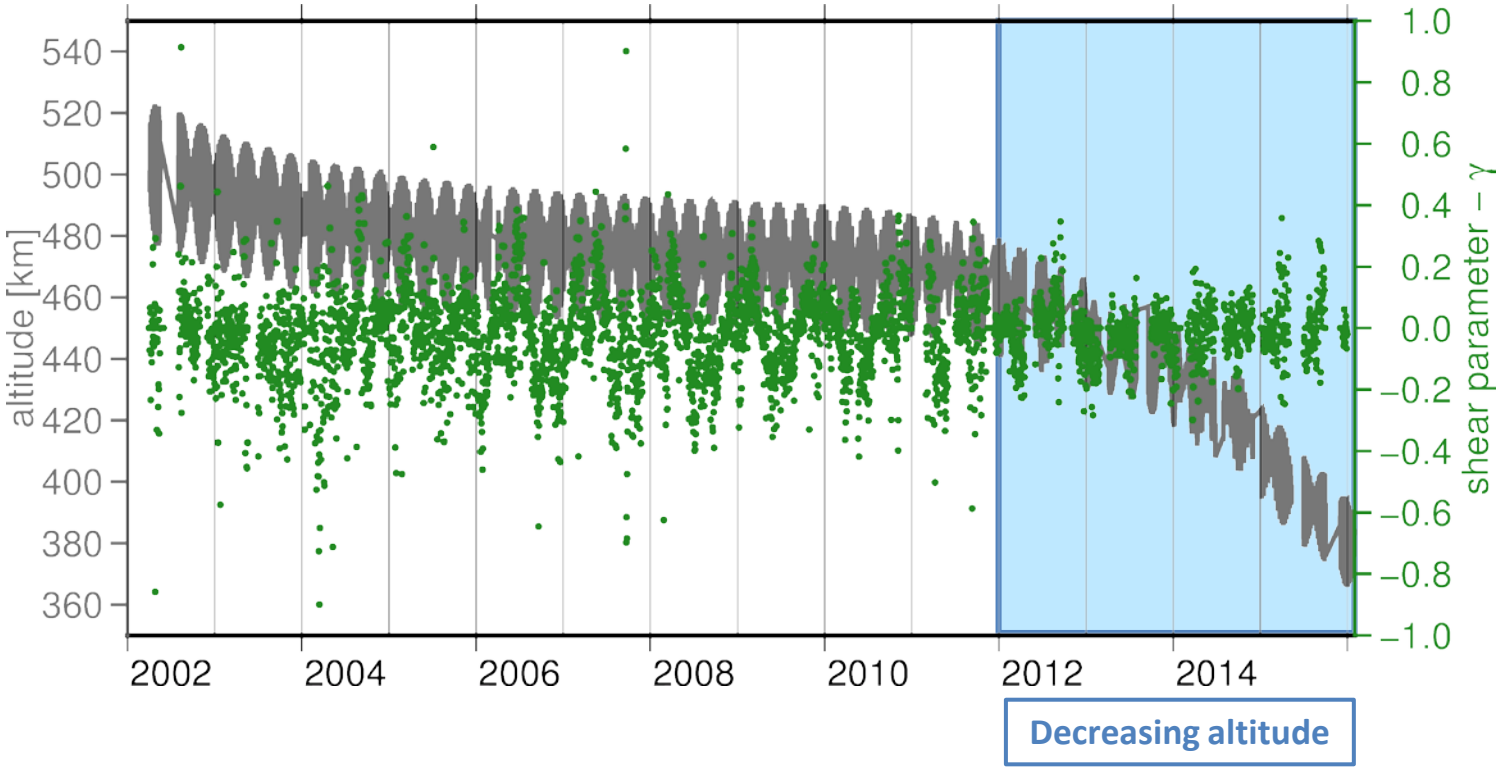
Beta prime angle (β‘)

- 161-day periodic signal



Altitude

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



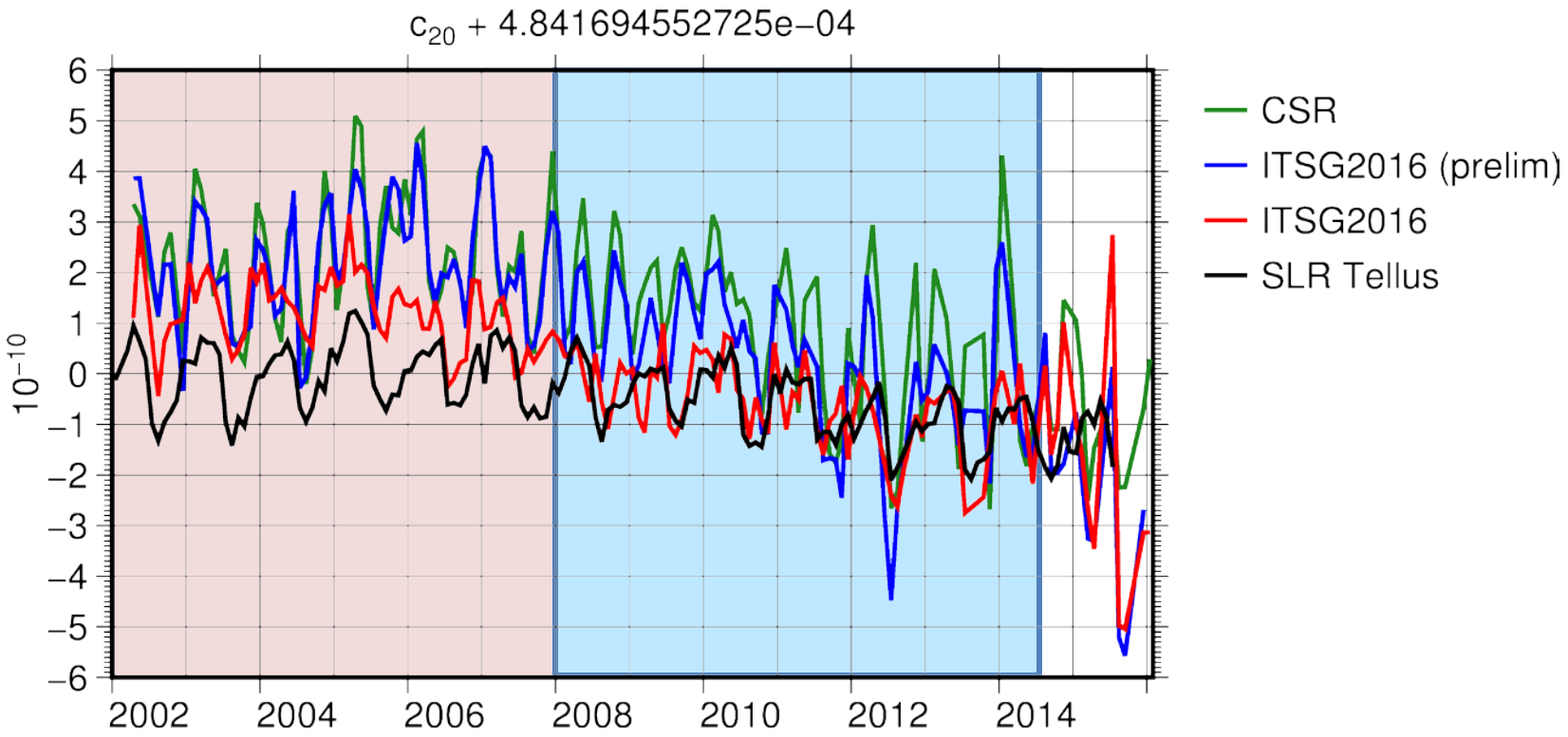
Impact on C20

ITSG-Grace2016 (prelim):

- Main diagonal elements only

ITSG-Grace2016:

- Fully-populated scale factor matrix



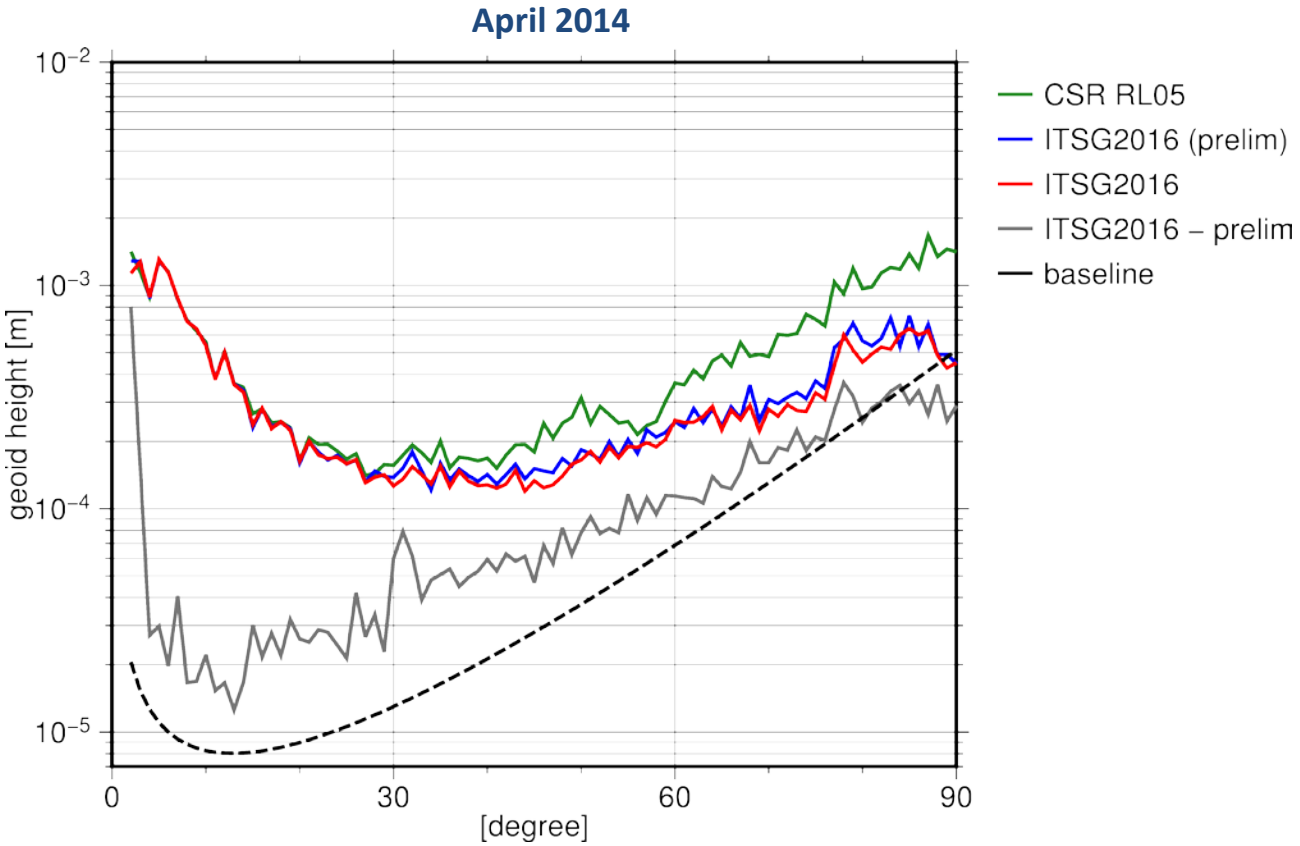
Impact on C20

ITSG-Grace2016 (prelim):

- Main diagonal elements only

ITSG-Grace2016:

- Fully-populated scale factor matrix



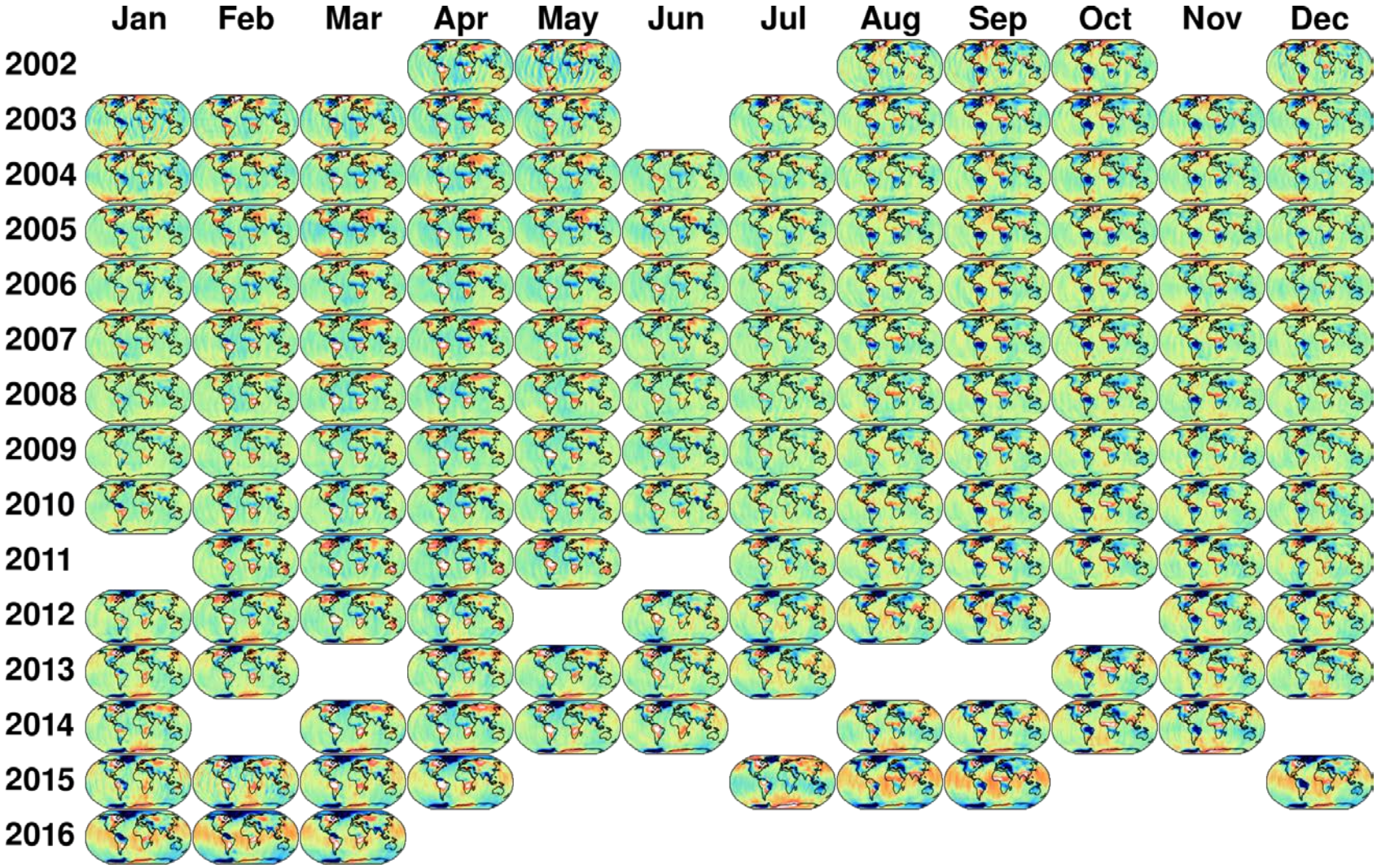
Summary & Conclusions

- GRACE accelerometers are extremely sensitive to satellite-internal temperature variations
- Temperature-induced variations of calibration parameters (biases & scale factors)
- Fully-populated scale factor matrix significantly improves estimates of C20 coefficients (w.r.t SLR data)

- Further analysis: ideal parametrization of calibration equation

ITSG-Grace2016

ITSG-Grace2016 Monthly Solutions



ITSG-Grace2016 Monthly solutions

Method:

- Variational equations
- 24h arc length, 3h covariance length

Input:

- GRACE Level-1B data from 2002-04 to 2016-03
- ITSG orbit product (Zehentner et al. 2015)
- Improved satellite attitude (Klinger et al. 2014)

Unconstrained monthly solutions:

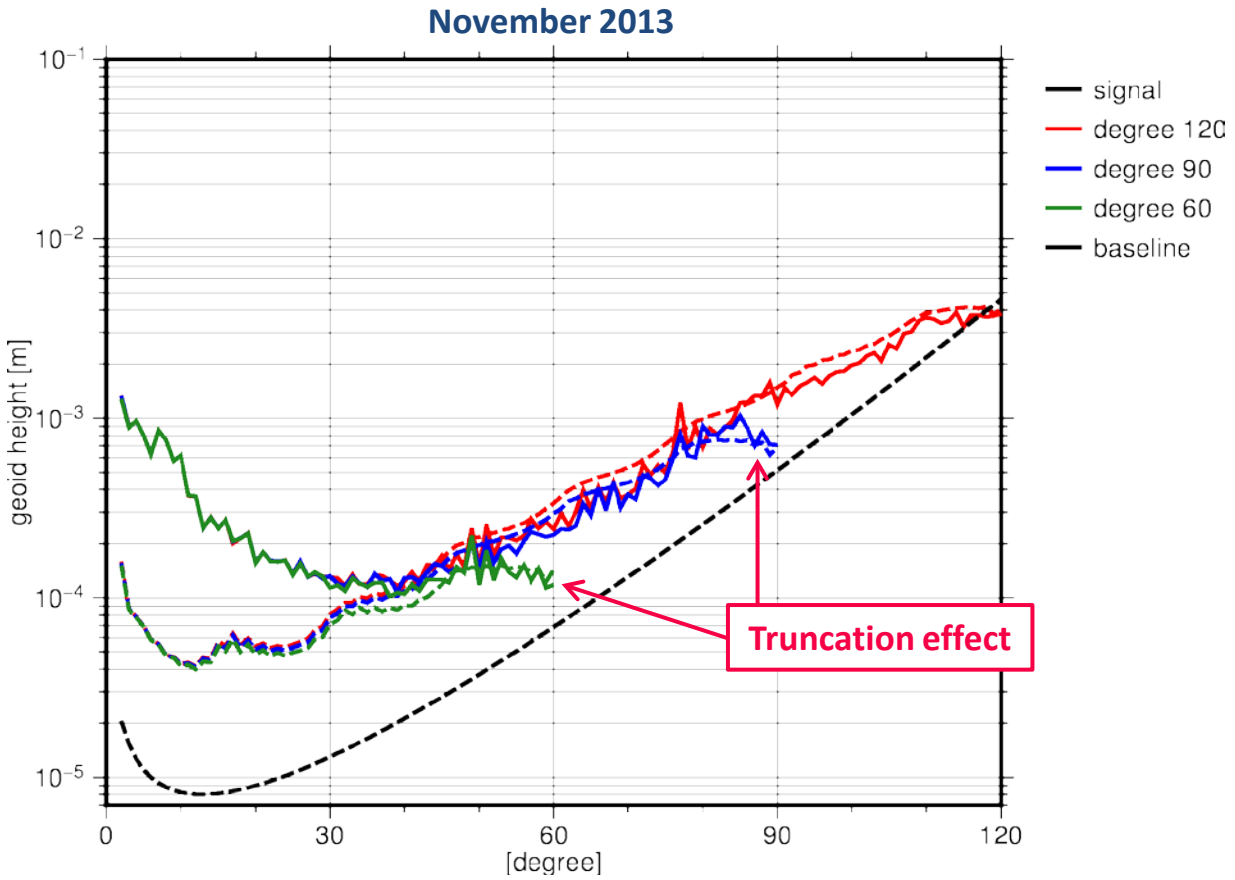
- Degree 60, 90, 120

Non-gravity parameters:

- Once per day: satellite state vector, accelerometer bias per axis (basis splines), accelerometer scale factors

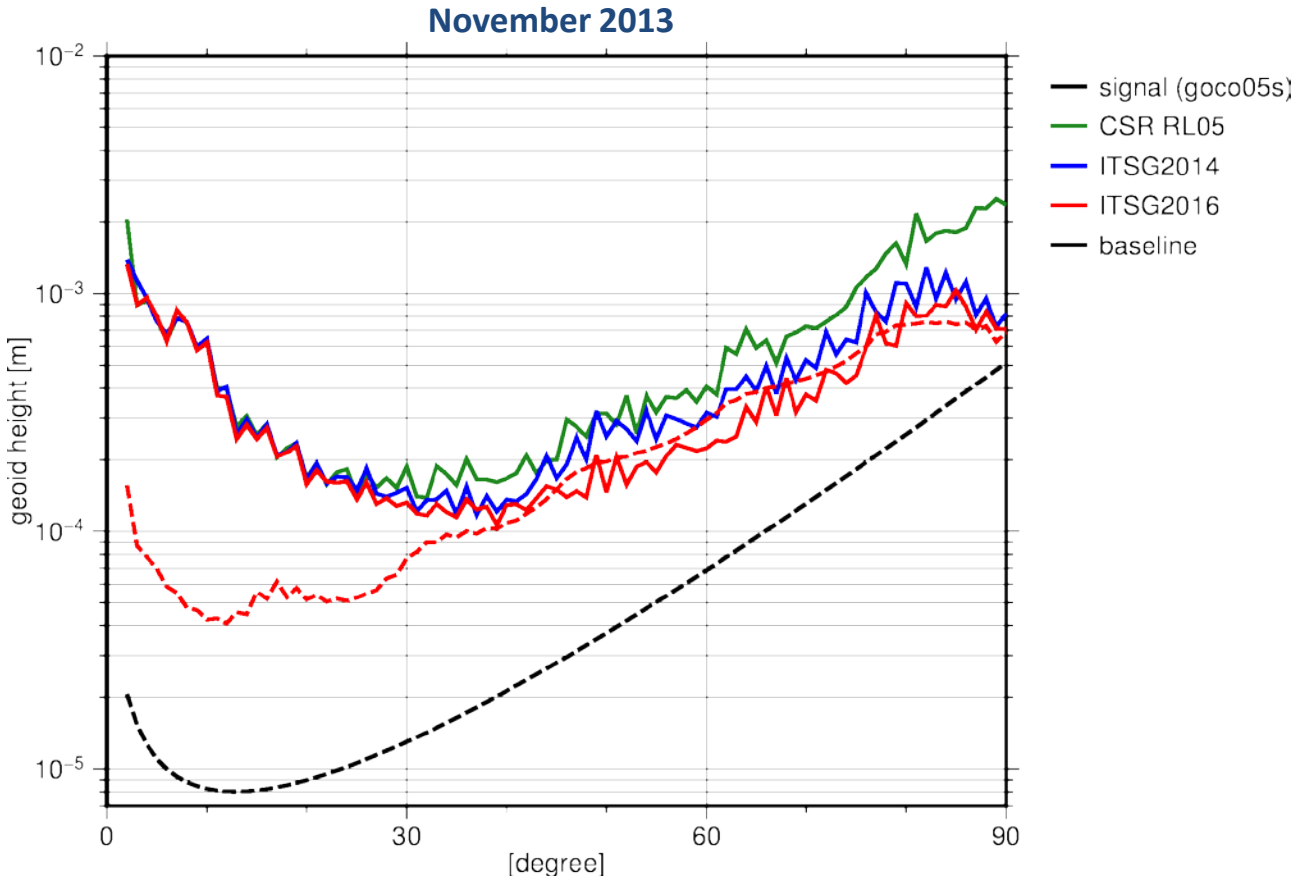
ITSG-Grace2016 Monthly Solutions

- **Unconstrained monthly solutions:** degree 60, 90 and 120

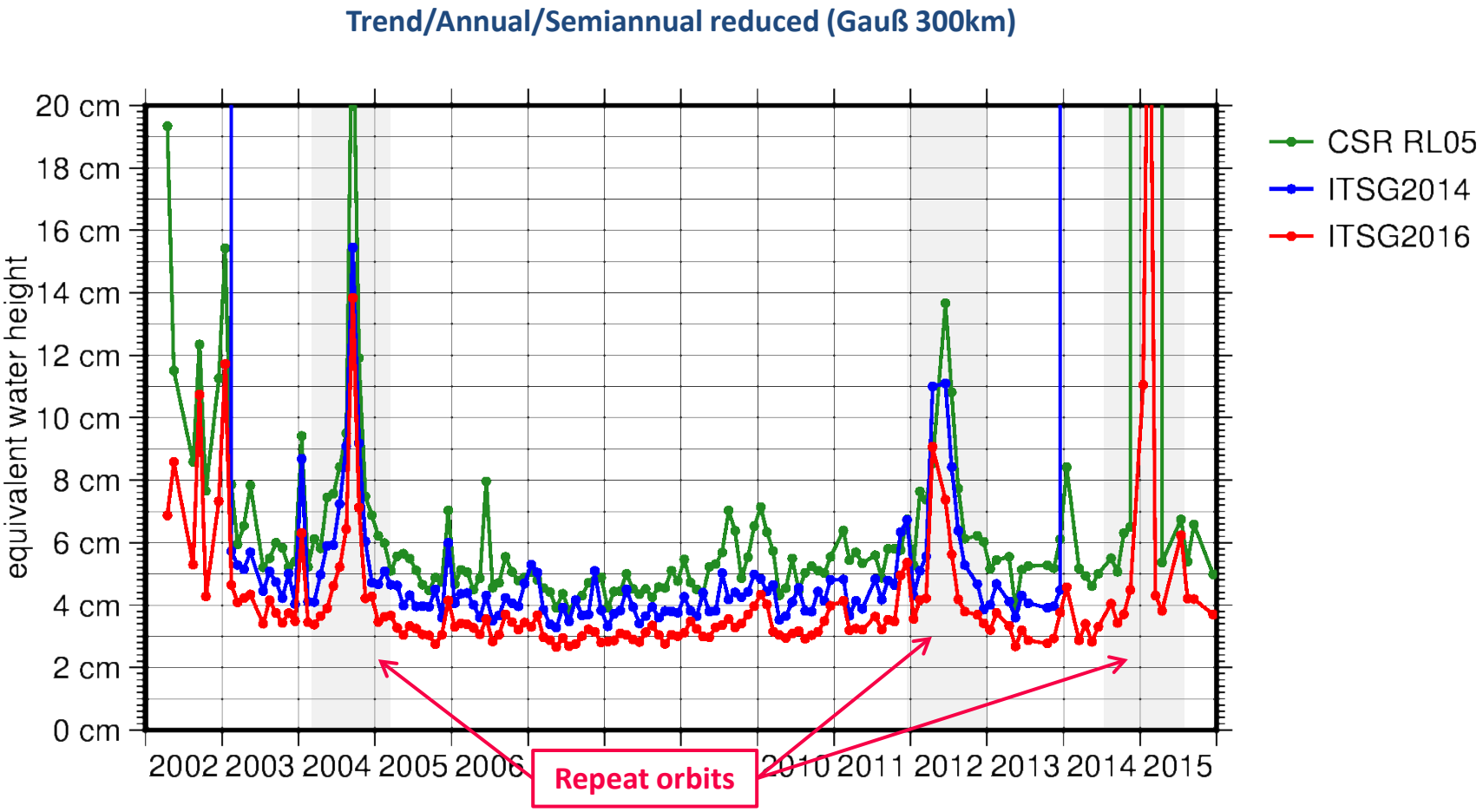


ITSG-Grace2016 Monthly Solutions

- **Unconstrained monthly solutions:** degree 60, 90 and 120



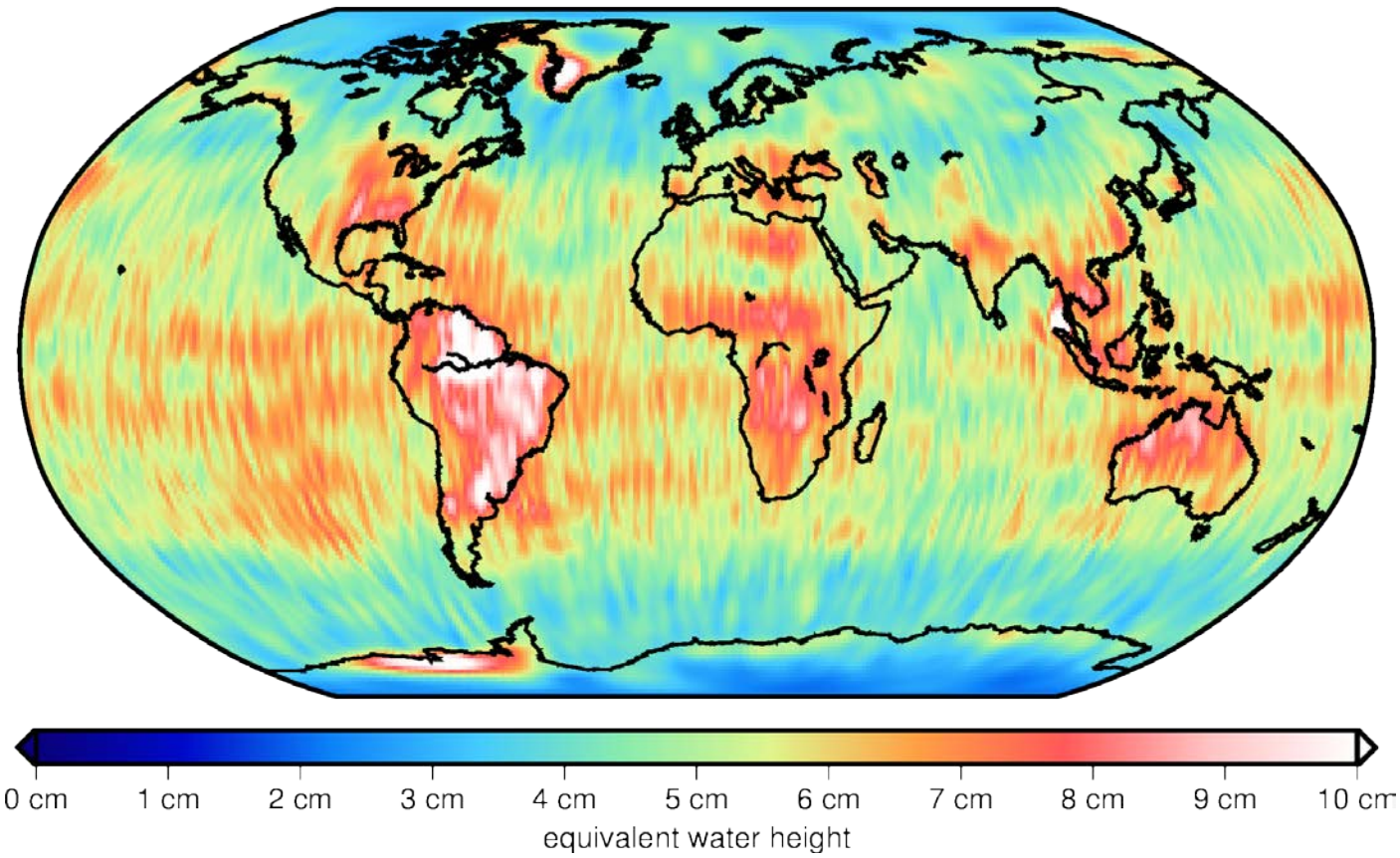
Variability over the Oceans



Temporal RMS

CSR RL05 - trend/SA/SSA (Gauß 300km)

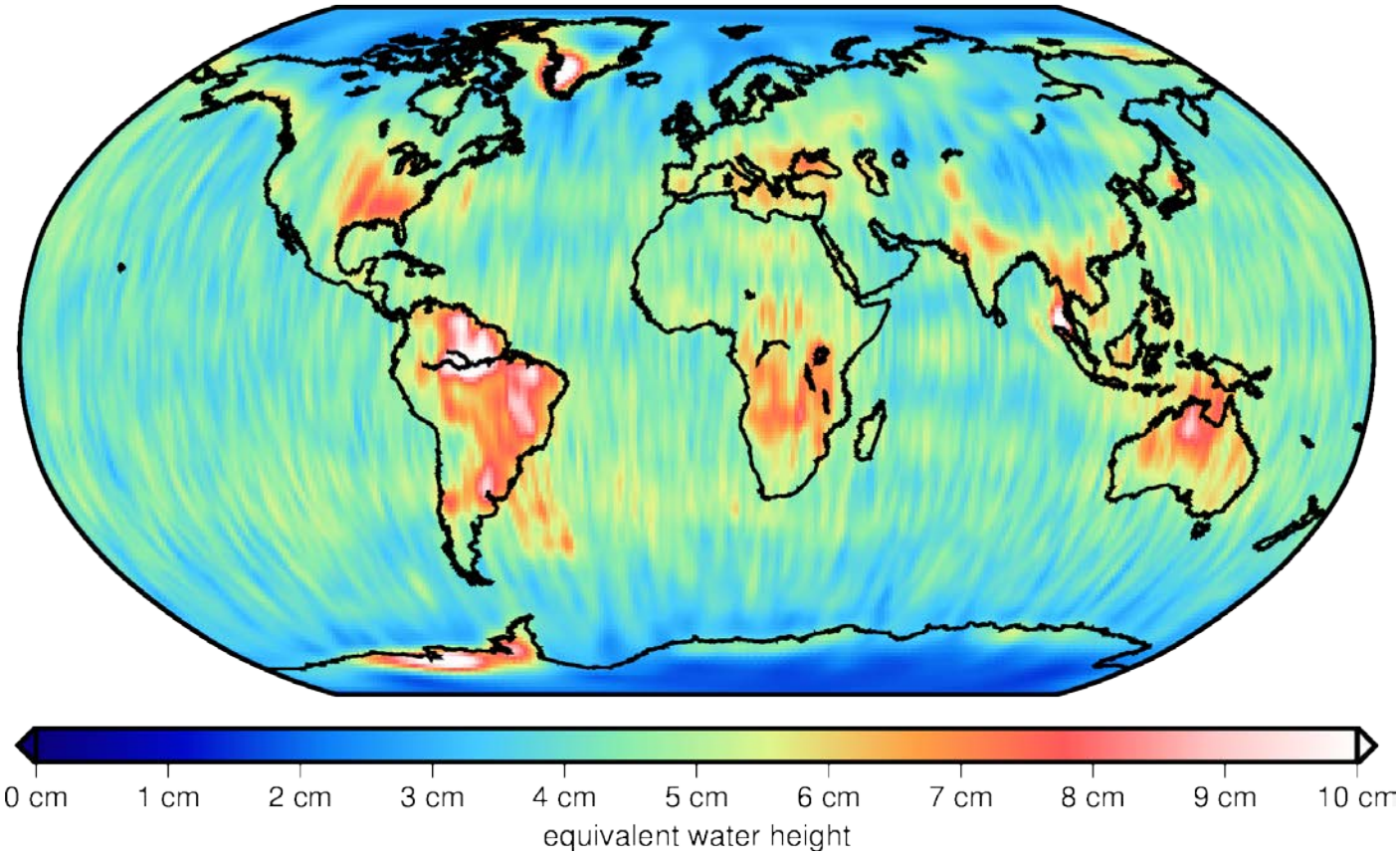
RMS = 5.5901



Temporal RMS

ITSG-Grace2014 - trend/SA/SSA (Gauß 300km)

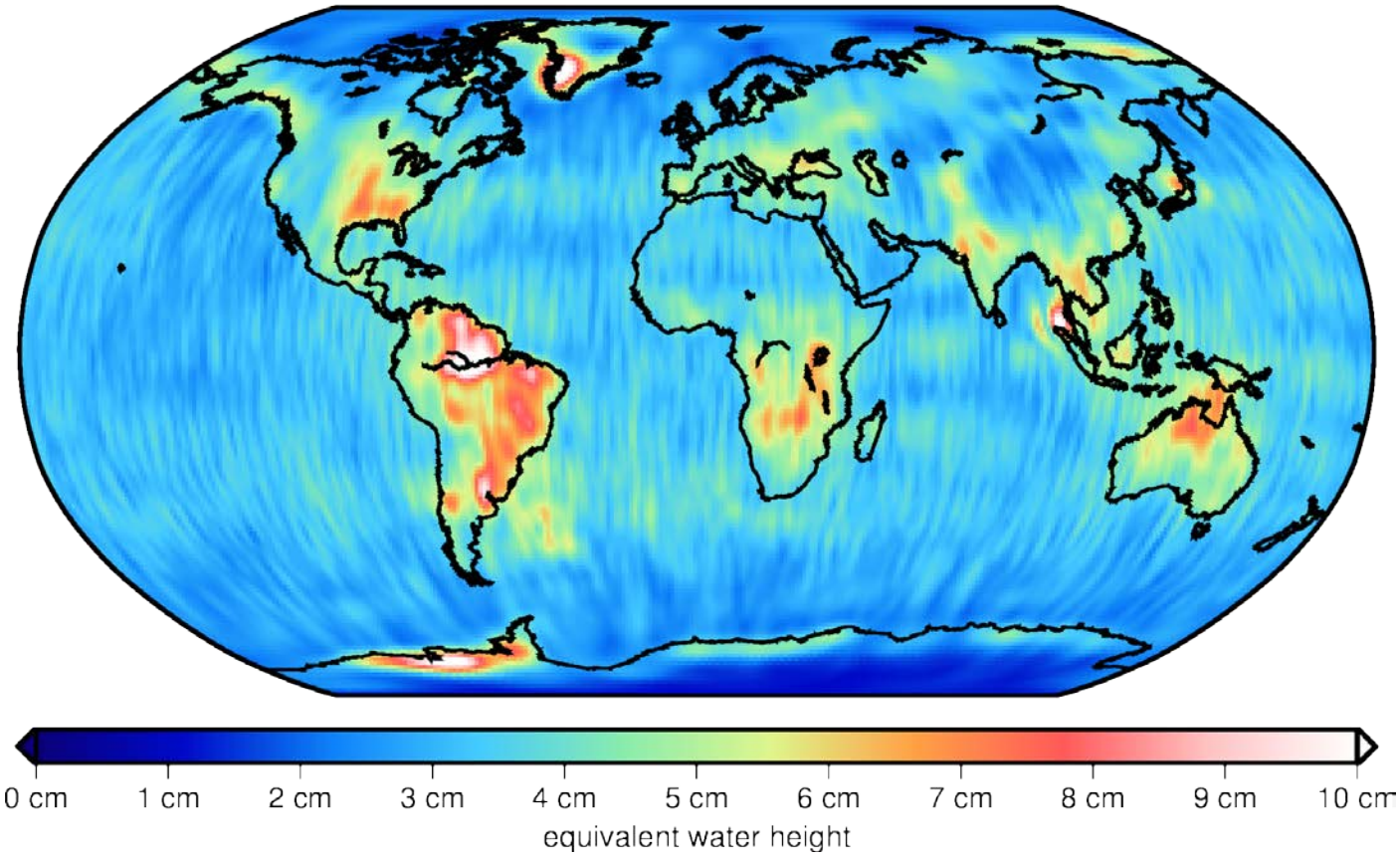
RMS = 4.6011



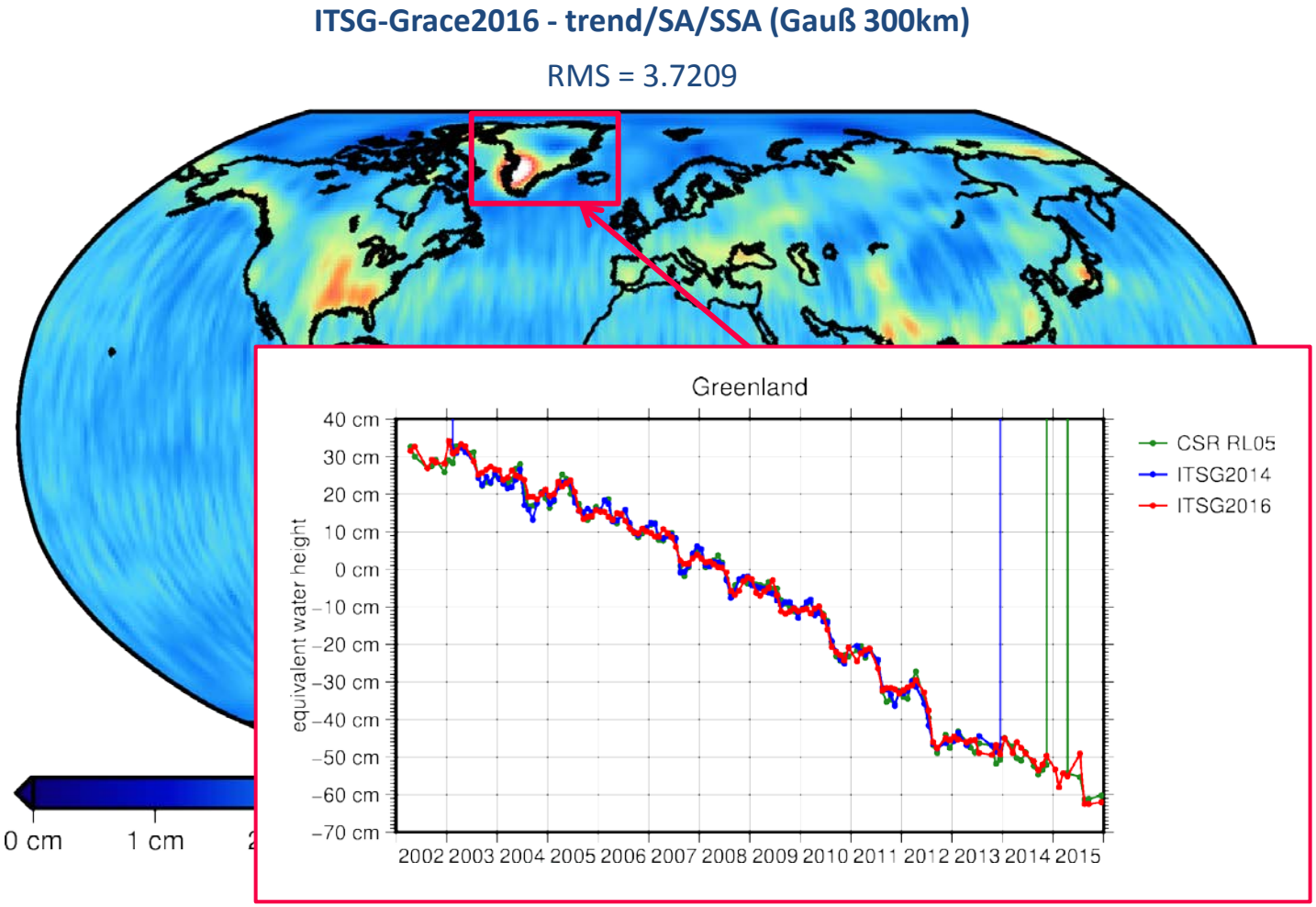
Temporal RMS

ITSG-Grace2016 - trend/SA/SSA (Gauß 300km)

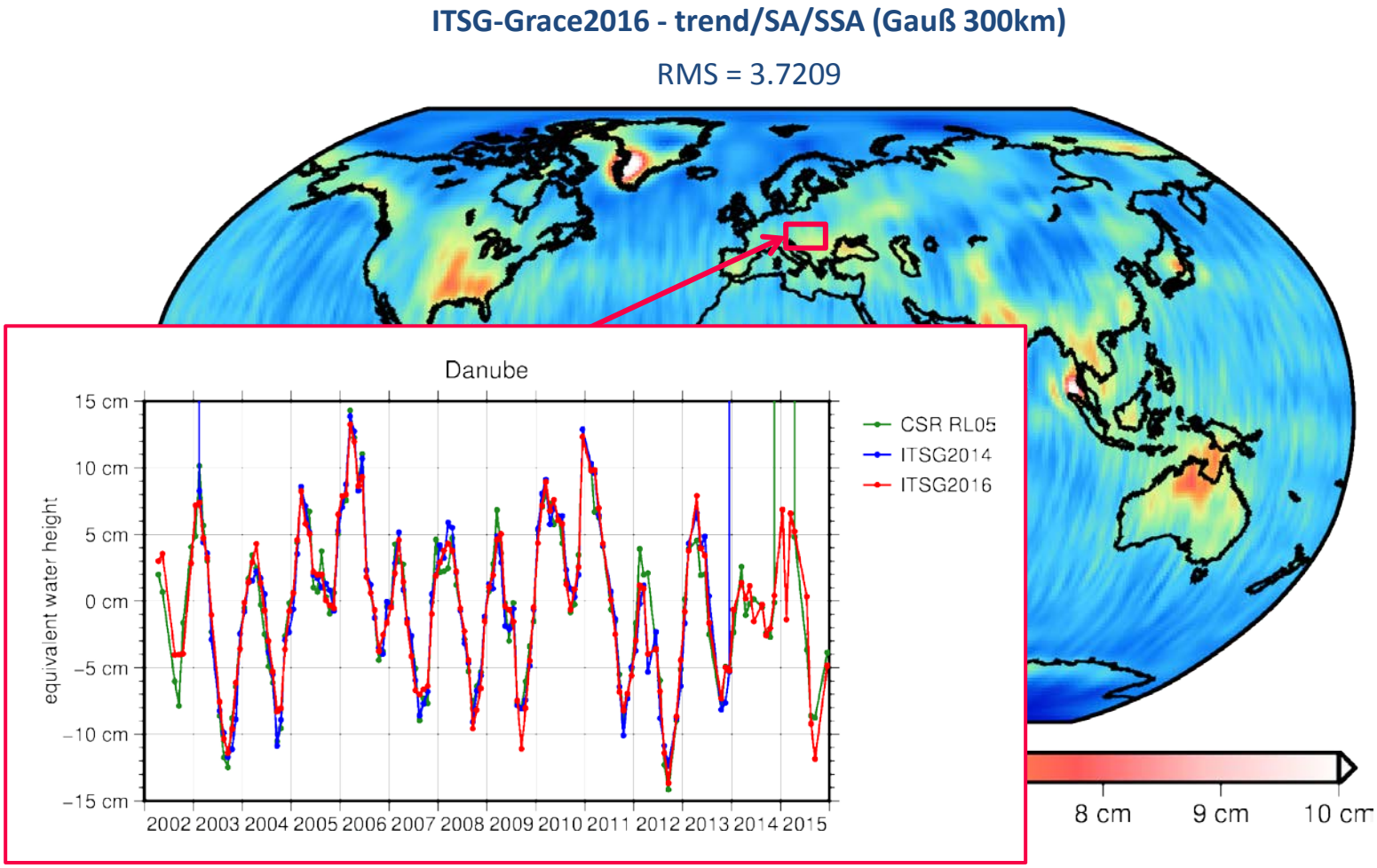
RMS = 3.7209



Comparison of signals



Comparison of signals



Summary & Conclusions

ITSG-Grace2014 vs. ITSG-Grace2016:

- Improved processing (data screening, accelerometer calibration, orbit integration, covariance function, …) contributes to overall accuracy of monthly gravity field solutions
- Noise reduction w.r.t ITSG-Grace2014 in the order of
  - 20% for n = 15-25
  - 40% for n = 25-40
  - 25% for n = 40-90 (Horwath et al., 2016)
- Fully-populated scale factor matrix significantly improves C20 coefficients

ITSG-Grace2016

Unconstrained monthly solutions:

- Degree 60, 90 and 120
- Full normal equations in SINEX format are published

Daily Kalman smoothed solutions:

- Degree 40

New ITSG-Grace2016 Release available at:

- ifg.tugraz.at/ITSG-Grace2016

Title: **Improved processing tools at TUG**

Presenter: BK

Affiliation: TUG

EGSIEM Meeting Potsdam,
02.06.2016 - 03.06.2016