Error modeling validation of GRACE gravity data

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Introduction

- The efforts to understand the error content of the GRACE (Gravity Recovery and Climate Experiment) observations continue for further improvement of gravity field models and preparation of GRACE-Follow On data processing setup.
- To identify **un-modelled errors**, a carefully inspection of the range rate post-fit residuals from the ITSG-Grace2016 gravity model [1]**,** is performed in the spatial, temporal and frequency domain. This investigation indicates **systematic errors due to eclipse crossings** in frequency range of 3 to 10mHz.
- From gravity field modeling point of view, eclipse crossing errors can be interpreted as a **temporary bias** term on the **range rate measurements**.
- Depending on the month under study, co-estimation of this calibration parameter in the ITSG-Grace2018 [2] scheme for the available level-1B (RL03) data improves the solution up to 3% RMS over the oceans..

Gravity field recovery from GRACE observations

Linear system model: $l = Ax + e \quad e \sim \mathcal{N}(0, \Sigma_{ll})$

Parameter estimation: $\hat{x} = (A^T \Sigma_{ll}^{-1} A)^{-1} A^T \Sigma_{ll}^{-1} l$

Gravity parameters: $\bar{c}_{nm}, \bar{s}_{nm}$

Postfit residuals: $\hat{e} = A\hat{x} - l$

Systematic errors

- Long term errors in **frequency band 3-10mHz** cannot be described stochastically nor corrected before gravity field recovery, affecting both residuals and gravity parameters.

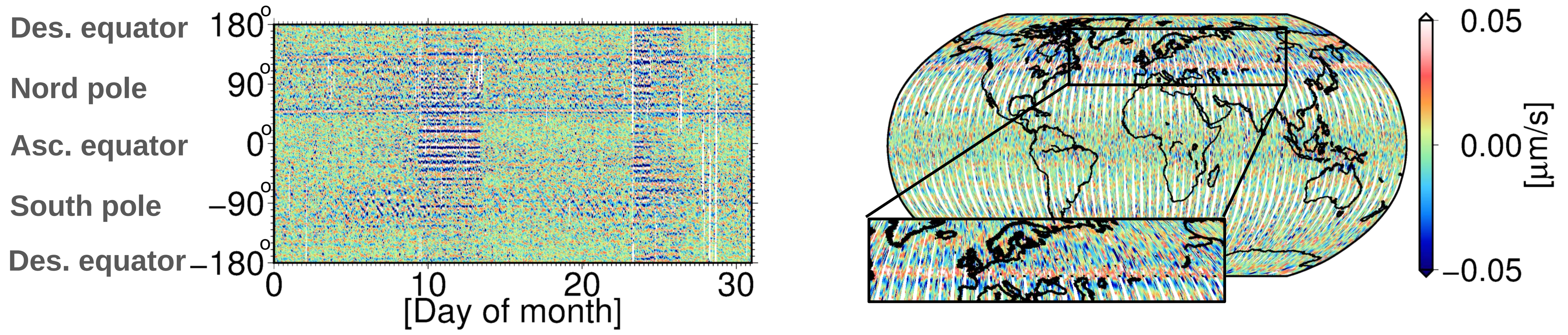

Fig.1: Filtered residuals in 3-10 mHz band with respect to GRACE-A (left) argument of latitude (right) ground-track (May 2004).

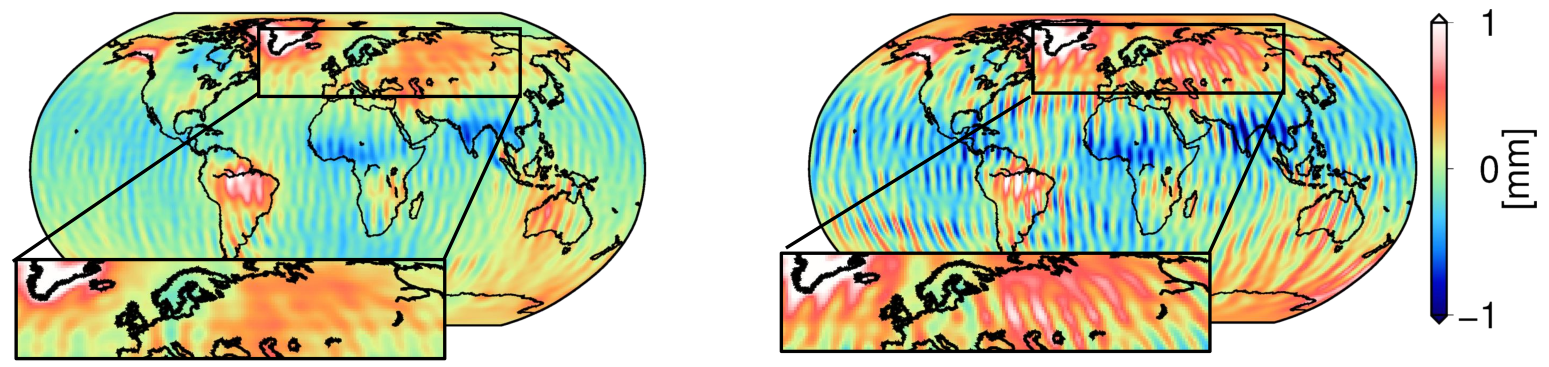

Fig.2: Temporal geoid height variations w.r.t GOCO05s static model from (left) ITSG-Grace2016 (right) Official GRACE solutions CSR RL05 (May 2004).

Eclipse transit phase

- Further investigation revealed a high correlation between the long-term errors and the **eclipse transit phases** of GRACE-A and GRACE-B.
- **Satellite eclipse factor ν** [3]: .
  $\nu = 0$ full shadow,
  $\nu = 1$ sunlight,
  $0 < \nu < 1$ transit phase.
- **Mission eclipse transit:**
  $\Delta\nu = \nu_B - \nu_A$.
  ν_B is GRACE-B eclipse factor,
  ν_A is GRACE-A eclipse factor.
- GRACE-A eclipse crossings causes **positive peaks**, GRACE-B eclipse crossings causes **negative peaks**.

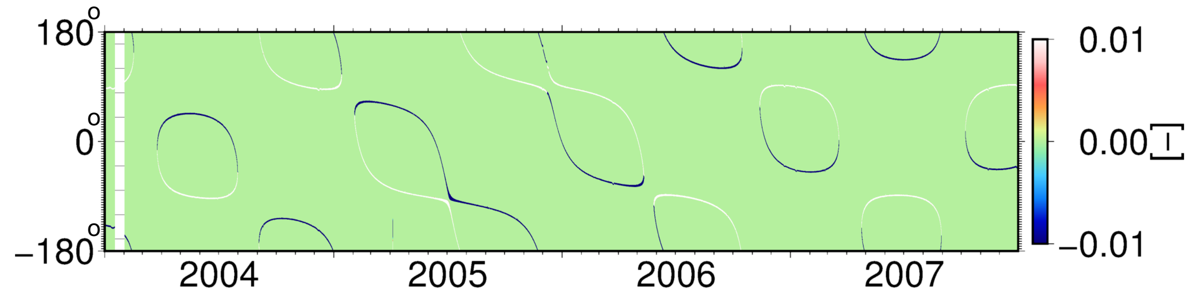

Fig.4: Mission eclipse transit w.r.t. GRACE-A argument of latitude.

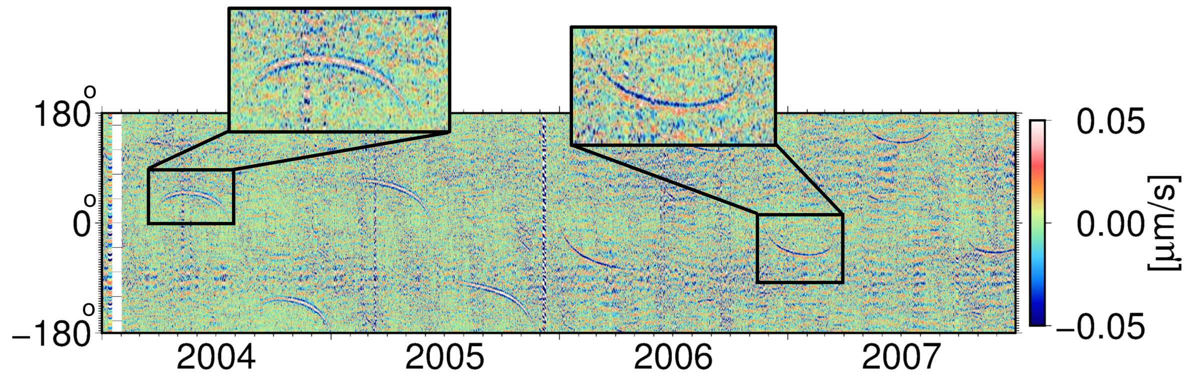

Fig.5: Filtered residuals w.r.t GRACE-A argument of latitude.

Charachteristics of errors

- $\Delta\nu$<0: Errors occurrence.
- Two swap maneuvers in December 2005 and July 2014.
- **Before December 2005 and after July 2014**: GRACE-A is the leading satellite,
  $\Delta\nu < 0$: the pair are **entering the shadow**.
- **Between December 2005 and July 2014**: GRACE-B is the leading satellite,
  $\Delta\nu < 0$: the pair are **entering the sunlight**.

Error modeling

- Approach: Estimate the calibration parameter b within the framework of LS adjustment.

Error model: $e = B(t)b + e_s \quad e_s \sim \mathcal{N}(0, \Sigma_{ll})$

Linear system model: $l = Ax + B(t)b + e_s$

Updated system model: $l = [A \quad B] \begin{bmatrix} x \\ b \end{bmatrix} + e_s$

- Temporal bias $B(t)$: Impulse signals at transit phase + GRACE low pass filter

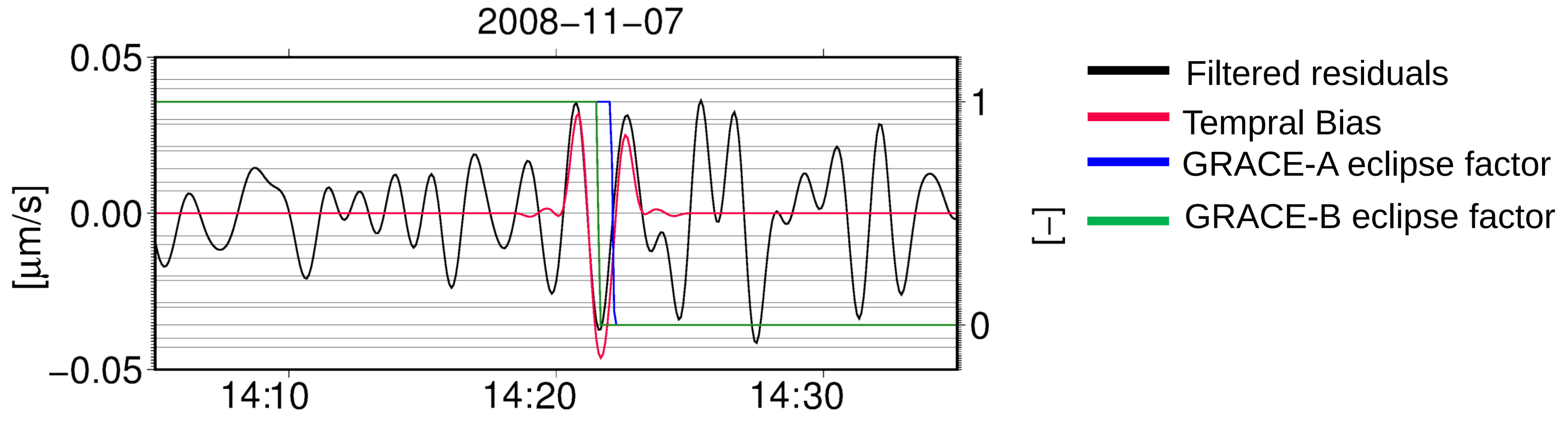

Fig.6: Tempral bias function in time domain, compared to filtered residuals.

Improving gravity field

- Solutions are computed based on ITSG-Grace2018 scheme.
- Bias estimation affects gravity field solution degrees above 40.
- Improvement depends on month and the distribution of the errors.
- For available data, solutions are improved up to 3% RMS over the oceans and 2% RMS overall.

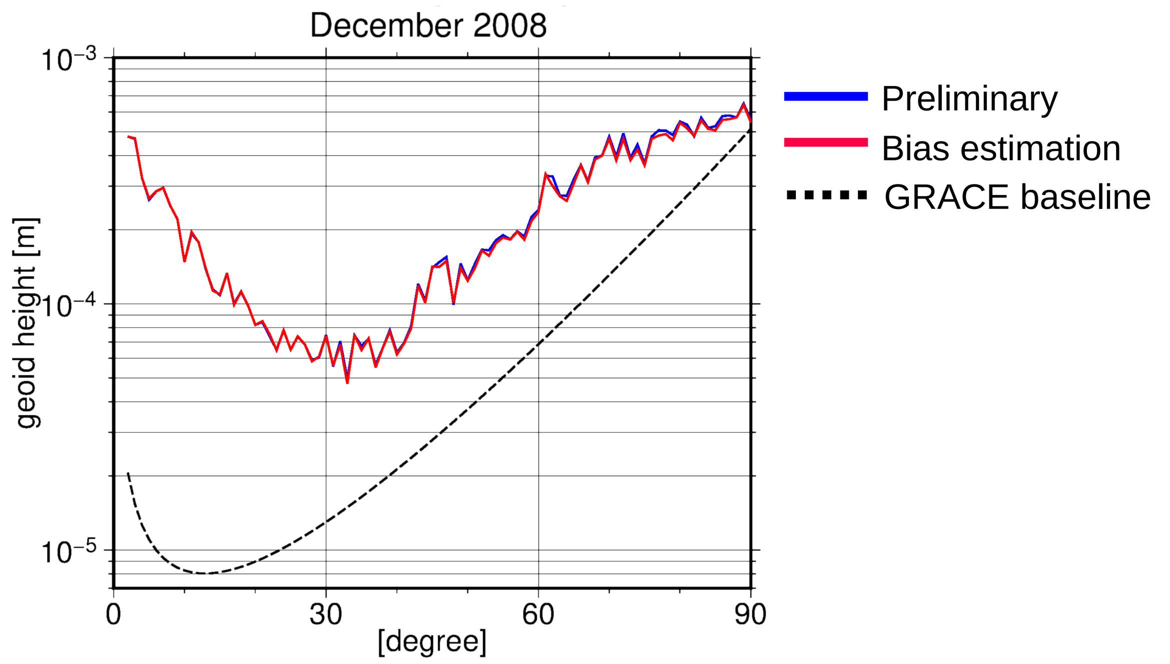

Fig.7: Degree variances w.r.t GOCO05s static model.

Reducing range rate residuals

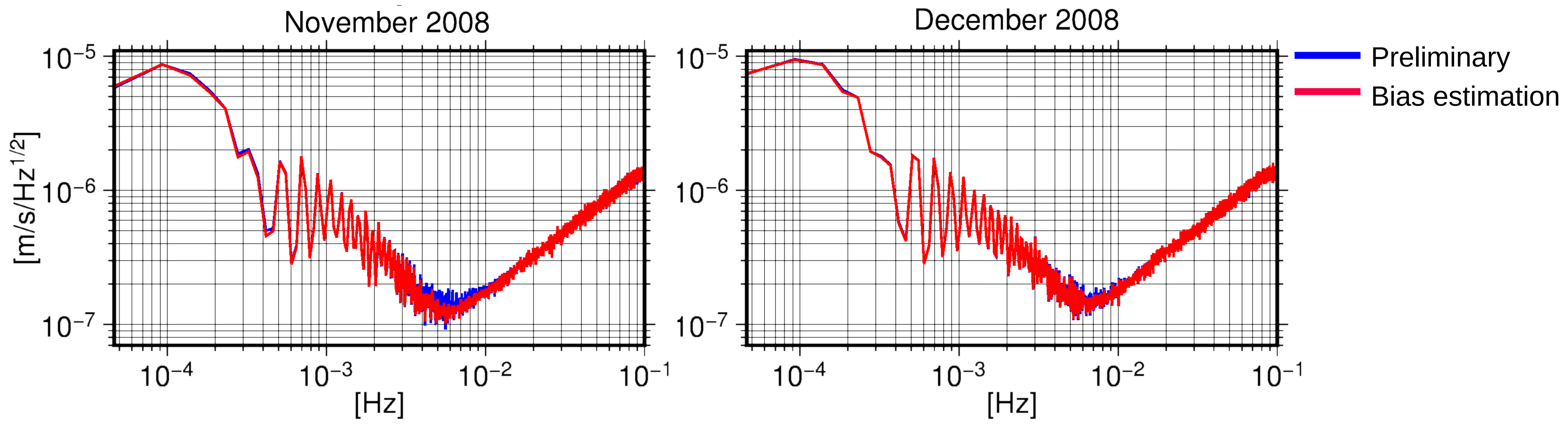

Fig.8: PSD of the range rate residuals of (left) November and (right) December 2008.

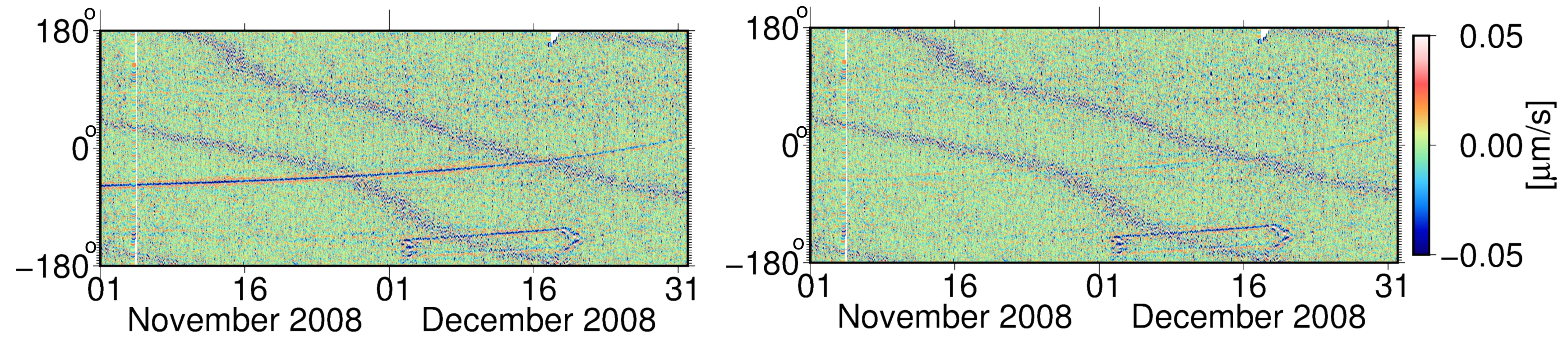

Fig.9: Filtered residuals with respect to GRACE-A argument of latitude from (left) preliminary and (right) bias estimation gravity solutions.

Outlook

- More studies are needed to define specific cause of the systematic errors.
- The implemented approach improves the gravity field solutions, but could be far from an optimal approach. For an optimal modeling, dynamic motion of the satellites and a more realistic eclipse model (e.g. with atmosphere model and the Earth's oblateness) should be considered.

Acknowledgments

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References

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