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Improved GRACE preprocessing methodologies: impact on monthly gravity field solutions

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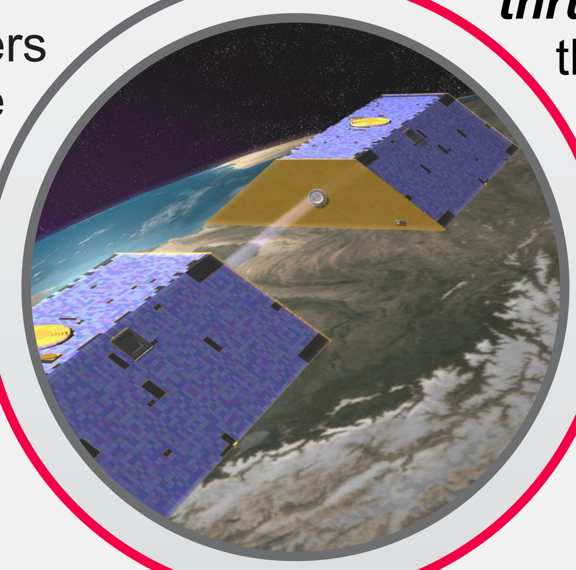
Introduction

The GRACE (Gravity Recovery and Climate Experiment) satellite mission provides K-band ranging (KBR) measurements between the two twin satellites GRACE-A and GRACE-B for the purpose of gravity field recovery. Although the accuracy of gravity field solutions has increased during the last years, there still remains an offset between the present error level and the GRACE baseline accuracy. Efforts are ongoing to identify the remaining error sources.

Both unmodeled errors within the Level-1b data products related to the alignment and outliers within the GRACE observations are potential contributors to the error budget. Even after more than 12 years of mission operation, improved modeling and preprocessing methodologies (sensor fusion, gap filling & data screening) contribute substantially to the overall accuracy of the recovered monthly gravity field solutions.



Data Preprocessing

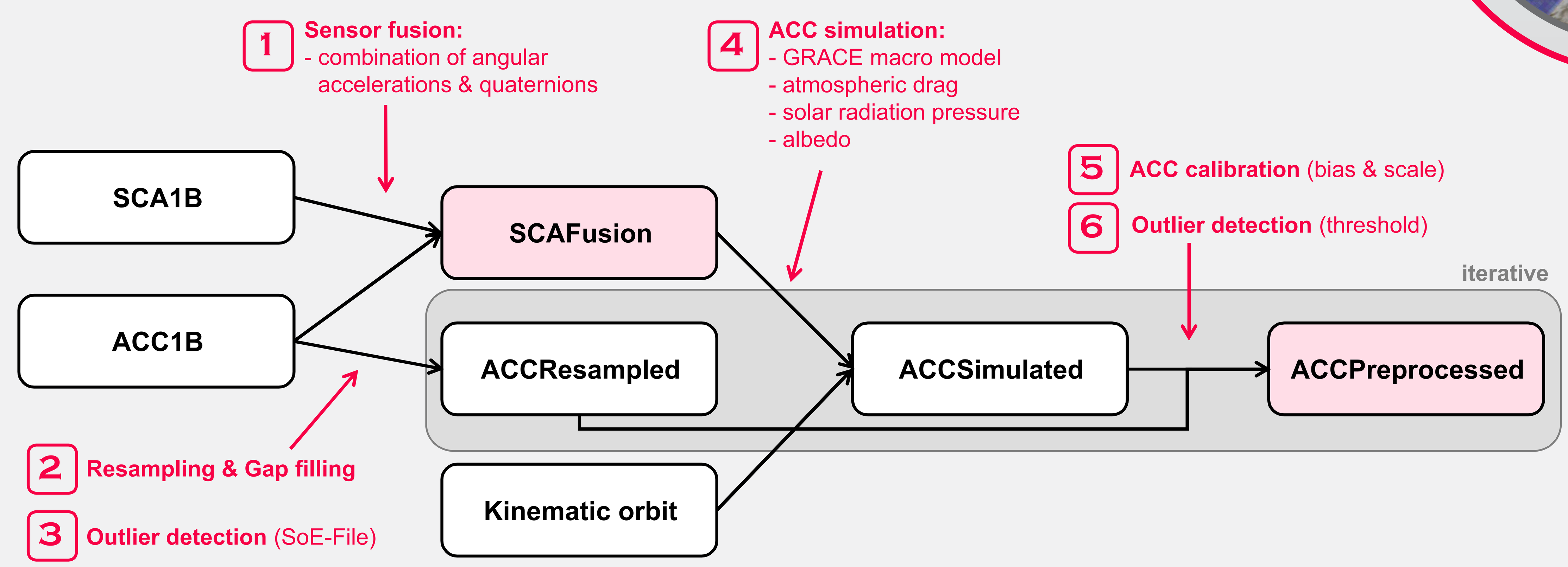


Fig. 1: Schematic diagram of the GRACE Level-1b data (star camera SCA1B, accelerometer ACC1B) preprocessing.

StarCamera: sensor fusion [1]

Combination of both angular accelerometer and star camera data (ACC1B, SCA1B) in a least squares adjustment to improve the satellites' attitude estimation:

- $\dot{\omega}(\mathbf{q},\dot{\mathbf{q}}) := 2\mathbf{W}(\mathbf{q})\ddot{\mathbf{q}}$

angular accelerations; Quaternion rate matrix; 2nd derivative of the unit quaternion

As a result, the high frequent noise within the attitude data can be decreased significantly (cf. Fig. 2).

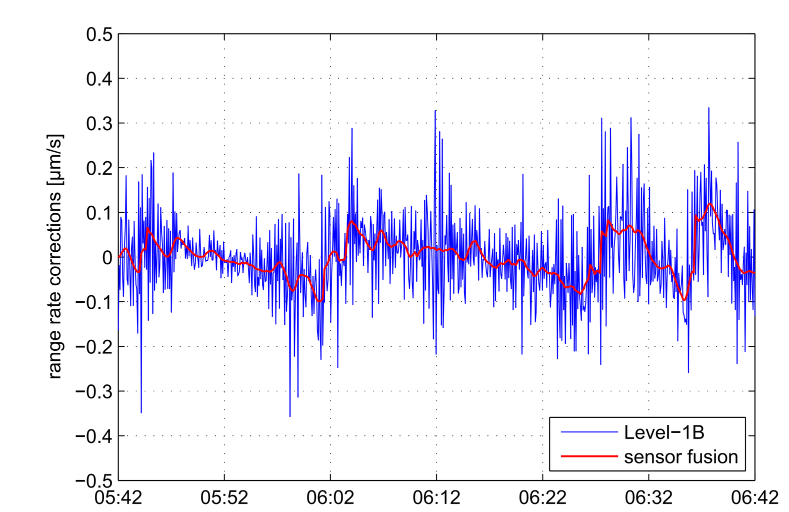


Fig. 2: KBR antenna offset range rate corrections for 1 hour. Blue graph: Level-1b data (KBR1B); red graph: AOCs derived from combined data (sensor fusion).

Accelerometer [4] [5] [6]

1) Simulation

The main non-gravitational forces acting on the spacecraft are due to ***atmospheric drag, solar radiation pressure, Earth albedo*** and ***thrusting***; these forces are measured by the onboard accelerometers.

Using the GRACE macro model, orbit, and attitude information these linear accelerations (in along-track, cross-track, and radial direction) can be modeled as well.

2) Calibration

The accelerometer scale is chosen according to GRACE TN-02. The accelerometer bias (offset & drift) is estimated as a polynomial w.r.t. the simulated data using the following equations:

- $\mathbf{acc_{sim}} = \mathbf{bias} + \mathbf{scale} \times \mathbf{acc_{1b}}$
- $\mathbf{bias} = \mathbf{c_0} + \mathbf{c_1}(t-t_0) + \mathbf{c_2}(t-t_0)^2 + \ldots + \mathbf{c_n}(t-t_0)^n$

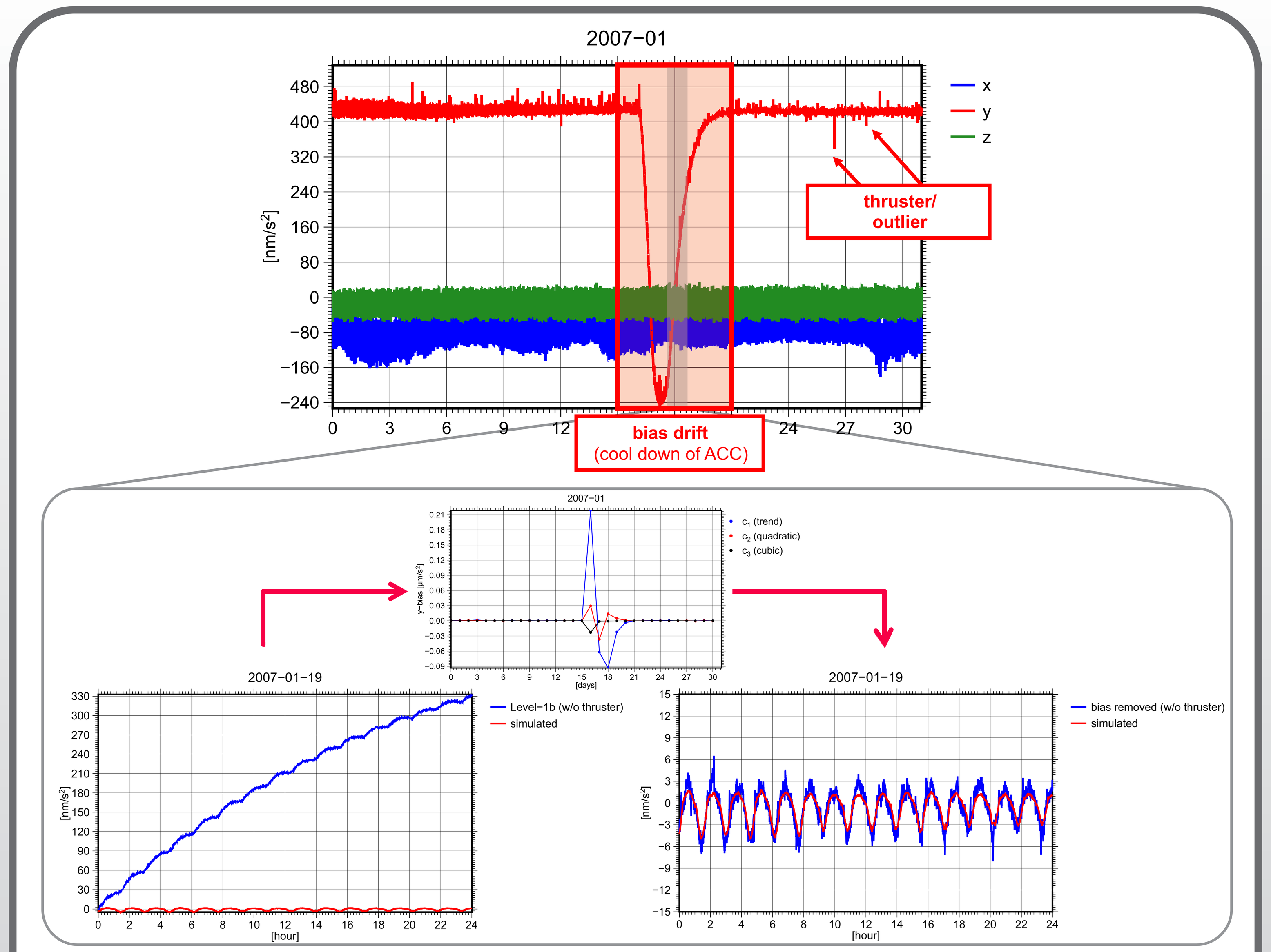


Fig. 3: Upper panel: GRACE-A Level-1b accelerometer data for January 2007 (bias & scale removed according to TN-02). Blue graph: along-track; red graph: cross-track; green graph: radial. **Lower panel:** Bias estimation for the along-track component w.r.t. the simulated data for one day (19th January 2007).

Gravity Field Recovery

Based on the ITSG-Grace2014 processing scheme different gravity field solutions for January 2007 were computed. Compared to the official release (**Scenario 1**), the data preprocessing was adapted in **Scenario 2** according to Fig. 1; including the combined star camera data, an improved data screening and an adapted accelerometer calibration. Additionally, the corresponding GFZ and CSR monthly solutions are displayed for comparison.

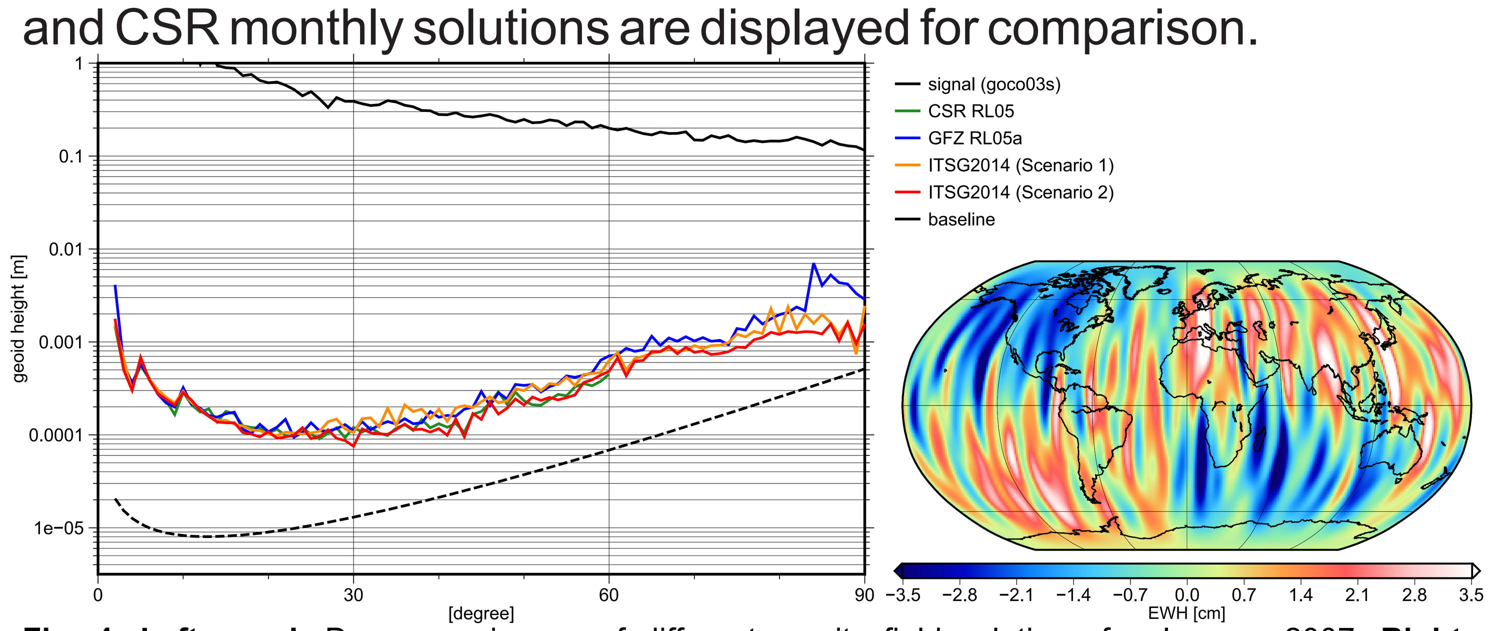


Fig. 4: Left panel: Degree variances of different gravity field solutions for January 2007. **Right panel:** Differences between Scenario 1 and Scenario 2 (500 km Gauß filter applied).

Conclusions

The presented results are based on improved preprocessing methodologies, including the sensor fusion approach and enhanced data screening and bias estimation.

Fig. 4 gives an impression of the achievable improvements compared to gravity field solutions of the official ITSG-Grace2014 release. The re-computed solutions show that even small changes within the preprocessing (e.g. bias drift rate estimation) contribute to the overall accuracy of the recovered monthly gravity field solutions, especially to the higher degrees.

The purpose of this work is to understand and to reduce the impact of possible error sources within the GRACE Level-1b data. Proper understanding of the science data is essential not only for increasing the accuracy of current solutions, but also for the development of future gravity field missions.

Acknowledgements

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