ITSG-Grace2016 data preprocessing methodologies revisited: impact of using Level-1A data products

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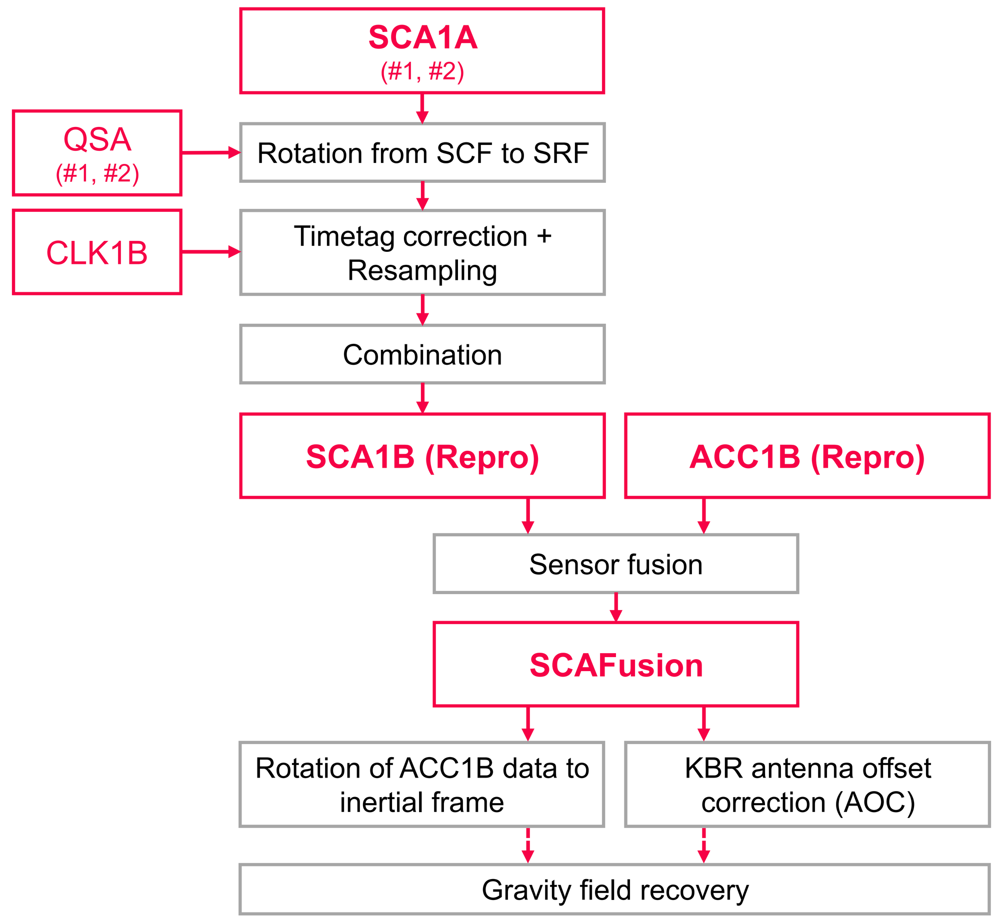
Introduction

For the ITSG-Grace2016 release, the gravity field recovery is based on the use of official GRACE (Gravity Recovery and Climate Experiment) Level-1B (RL02) data products, generated by the Jet Propulsion Laboratory (JPL). Before gravity field recovery, the Level-1B instrument data are pre-processed. This includes the combination of Level-1B star camera (SCA1B) and angular acceleration (ACC1B) data for an improved attitude determination (sensor fusion), instrument data screening and ACC1B data calibration.

Based on a Level-1A test dataset, provided for individual month throughout the GRACE period by the Center of Space Research at the University of Texas at Austin (UTCSR), the impact of using re-processed Level-1B data products within the ITSG-Grace2016 processing chain is analyzed.

We discuss (1) the Level-1A to Level-1B SCA and ACC data processing, (2) the attitude determination with re-processed ACC1B and SCA1B data using our Sensor fusion approach, and (3) the impact of the new attitude product on temporal gravity field solutions. The presented work aims not only at a better understanding of GRACE science data to reduce the impact of possible error sources on the gravity field recovery, but it also aims at preparing Level-1A data handling capabilities for the GRACE FO mission.

Star camera data processing - SCA1B (Repro)



The attitude of the GRACE spacecrafts w.r.t the inertial frame is an essential information needed for the gravity field recovery (cf. Fig. 1). As shown by [2] and [3], the current SCA1B (RL02) data product contains several errors; which propagate to the gravity field solutions. Additionally, the high frequent noise within the attitude data can be reduced by combining the star camera and angular accelerometer data (as shown by [5] and [1]). Therefore, we reprocessed the SCA1A data to derive correctly combined SCA1B (Repro) data, which is then used as input for our sensor fusion approach (SCAFusion).

Fig. 1: Processing scheme from SCA1A to SCA1B according to SCA_compress [7] using the correct weighting [2], and use of the reprocessed SCA1B (Repro) data within the ITSG-Grace2016 processing chain.

Sensor fusion - ACC and SCA combination [5]

Combination of angular accelerometer & star camera data in a Least Squares Adjustment (LSA):

- Functional relationship established through: $\dot{\omega}(\mathbf{q}, \dot{\mathbf{q}}) := 2\mathbf{W}(\mathbf{q})\ddot{\mathbf{q}}$ ($\dot{\omega}$: angular accelerations; $\mathbf{W}(\mathbf{q})$: Quaternion rate matrix; $\ddot{\mathbf{q}}$: 2nd derivative of the unit quaternion)
- Optimal weighting (angular accelerations, quaternions) by Variance Component Estimation (VCE)
- Angular accelerometer bias estimation
- Effect of non- quadratic accelerometer proof mass taken into account

Open issues & questions:

- Correct stellar aberration correction [3],
- SCA orientation & alignment: inter-boresight angle variations (thermal effects)

Sensor fusion - SCA1B (RL02) vs. SCA1B (Repro) vs. SCAFusion

Angular accelerations

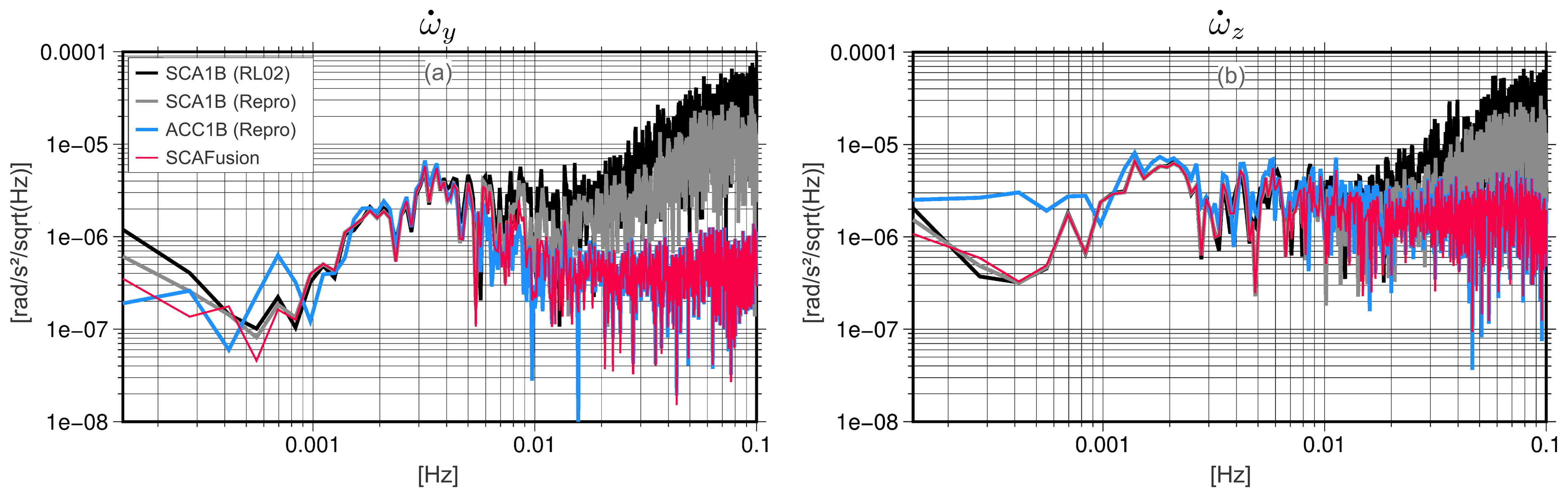


Fig. 2: Power spectral density (PSD) of angular accelerations in cross-track (a) and radial (b) direction for a 2h segment on 2011-09-01 for GRACE-A.

Antenna offset correction (AOC)

- Reduction of high-frequent attitude noise
- **SCA1B (Repro):** Switches between SCA heads lead to discontinuities (jumps) in derived AOCs (e.g., GRACE-B switches to SCA #2, cf. Fig. 3 (a))

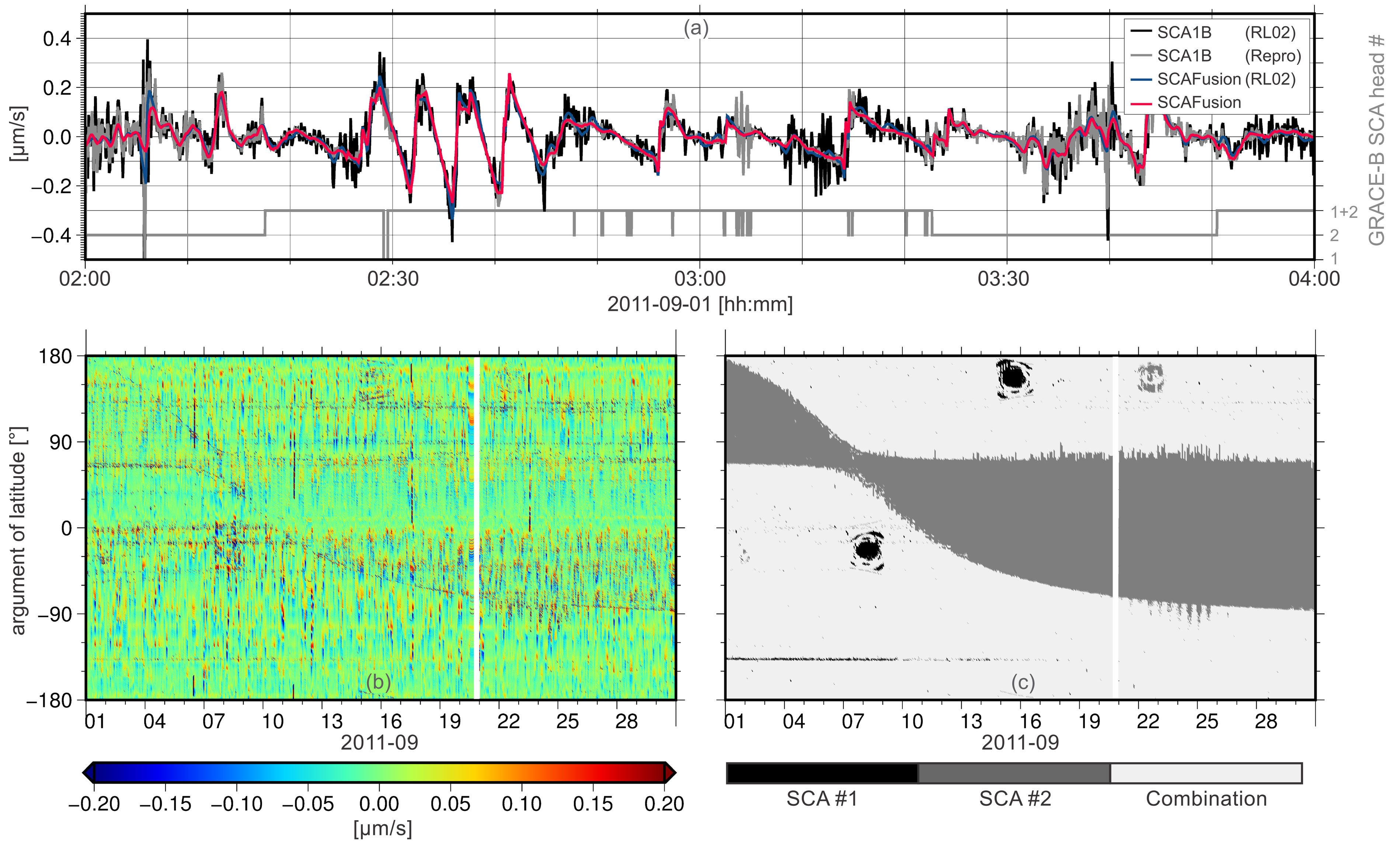
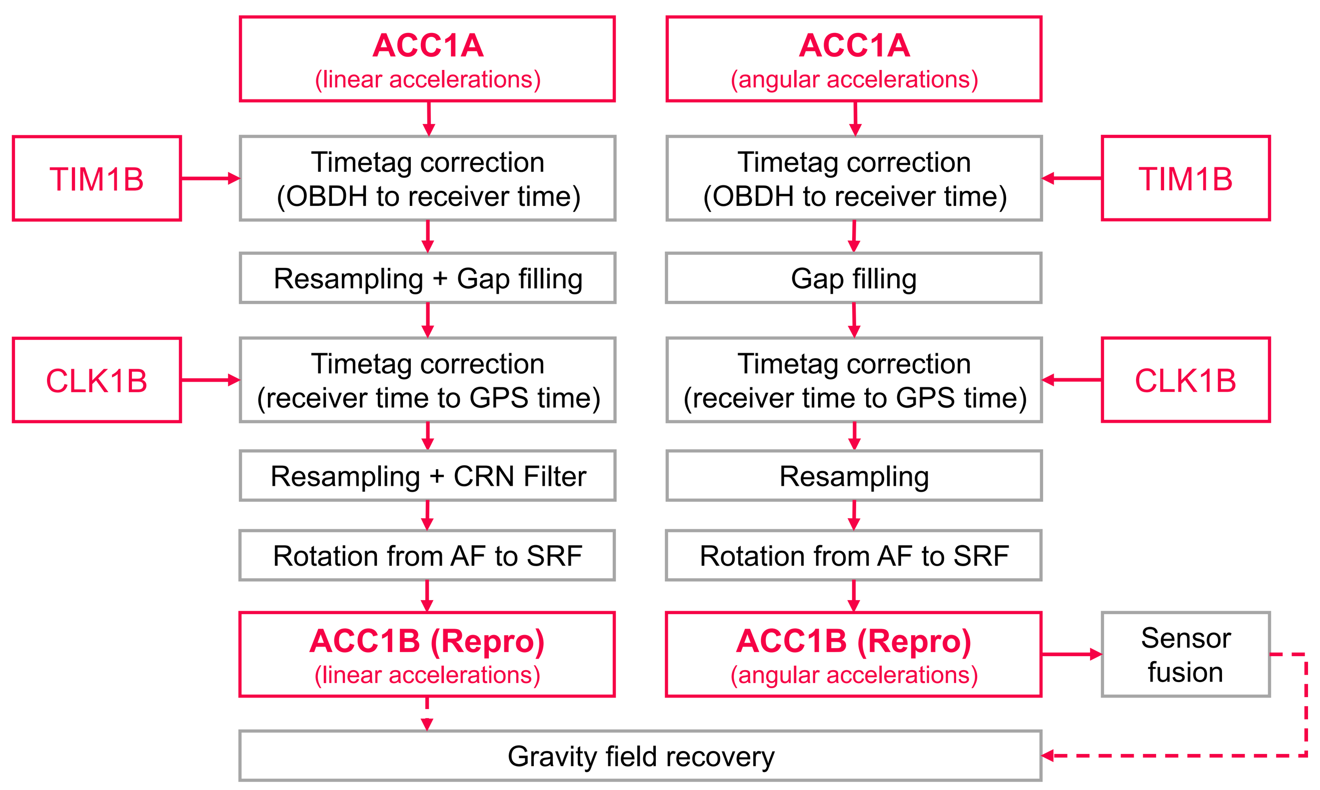


Fig. 3: (a) GRACE range rate antenna offset corrections (AOCs) for a 2h segment on 2011-09-01, (b) Range rate AOCs computed from the re-processed SCA1B (Repro) data for one month (2011-09), (c) SCA heads used for the computation of the SCA1B (Repro) data.

Accelerometer data processing - ACC1B (Repro)



Onboard each GRACE satellite is a three-axis capacitive accelerometer, measuring the non-conservative accelerations acting upon the satellites. In order to make use of the uncalibrated ACC1B data during gravity field recovery, bias and scale parameters have to estimated [4].

Fig. 4: Processing scheme from ACC1A to ACC1B according to ACC_compress [7] for linear and angular accelerations, respectively.

Linear accelerations

- High-frequent noise (cross-track, radial) related to the geomagnetic equator seems to be "amplified" during ACC1A to ACC1B processing (CRN Filter)

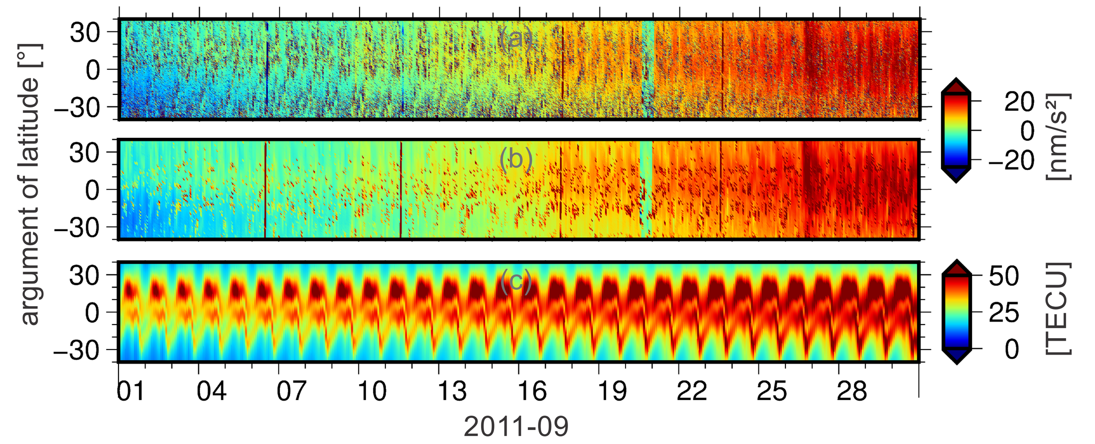


Fig. 5: Uncalibrated linear accelerations in radial direction: (a) ACC1A, (b) ACC1B (Repro); (c) Total Electron Content (IRI-2012) for 2011-09 for GRACE-A.

Impact on the gravity field recovery - ITSG-Grace2016 [6]

- Recovered gravity field solutions show no significant improvement
- Post-fit range rate residuals show a small reduction

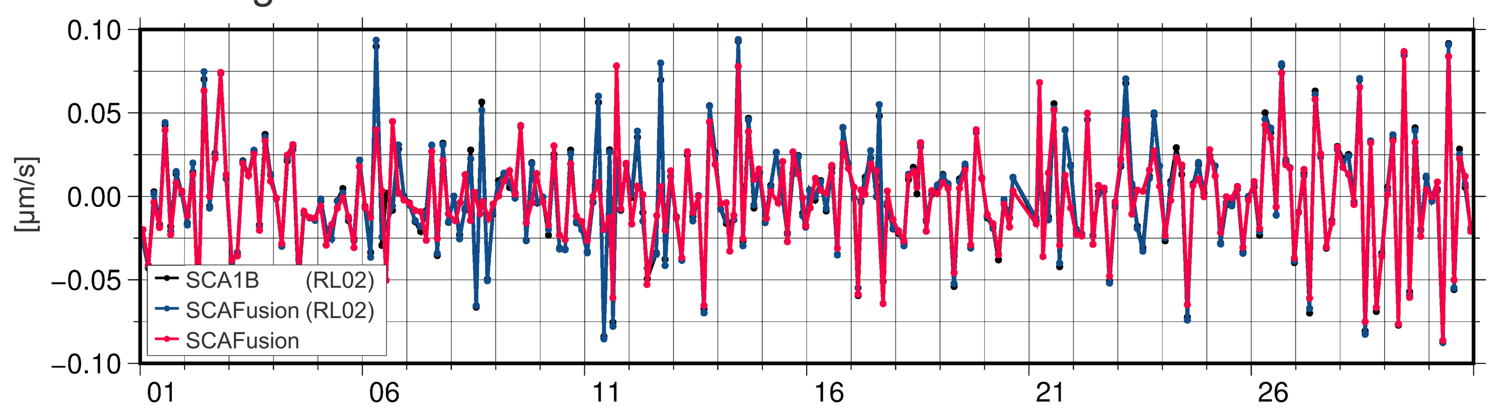


Fig. 6: Comparison of the arc-wise mean of the post-fit range rate residuals for one month (2011-09).

Outlook

Further research - SCA Sensor fusion:

- Direct use of SCA heads within Sensor fusion
- Optimal combination (weighting)
- SCA orientation & alignment (thermal effects)
- ⇨ Comparison with SCA1B RL03 data product [1]
- ⇨ Extension to 3 SCA heads for GRACE-FO

Further research - ACC:

- Outlier detection
- ACC data calibration [4]
- ⇨ Additional years, particularly later and noisier years (>2011-04), need to be further analyzed.

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