Improved Acceleration Modelling and Level 1 Processing Alternative for GRACE

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1. Introduction

GRACE is a dual satellite mission for measuring the gravity field of the earth and its temporal changes. The spacecrafts follow each other about 220 km apart on a near circular and polar orbit. The satellites are interconnected by a K-band microwave link measuring the exact separation distance and its rate of change to an accuracy of about 1µm/s. In order to take into account all non-gravitational forces, both spacecrafts are equipped with accelerometers. The accuracy of these sensors is 2 magnitudes better then in the previous mission CHAMP. How ever, maybe because of the sensitivity of these sensors, the observed signal contain several effects which are not sufficiently understood. Some of them are related to switching events in electric circuits, like heater switching and current changes in magnetic torquers. Other signatures, so called »twangs«, could up to date not be clearly resolved or correlated with any switching process. However, investigation and discussions are ongoing whether clanks or vibrations are the cause for these signatures.

2. Modelling of accelerometer spikes due to current changes in the magnetic torquers

If a source of a signature is identified, the spikes on the accelerometer can be modelled by superimposing the 10Hz accelerometer signal of many of these events and fitting the signal waveform. This procedure is allowed because the timing of the original signal is known and the 10 Hz measuring rate matches to the transfer function. This approach has already been used for heater switching events and is now translated to the current changes in the magnetic torquer coils.

The magnetic torquers are used for attitude control and maintenance of the satellite. In combination with the cold-gas thrusters and a processing unit onboard of the satellite the Attitude and Orbit Control System (AOCS) is formed. By changing the amplitude of the current through the magnetic coil of the magnetic torquer the magnetic moment evoked by the torquer is changed and the torsional moment acting upon the spacecraft in combination with earth magnetic field is varied.

With a significant quantity of both accelerometer and magnetic torquer data the spikes in the accelerometer data evoked by current changes in the torquer can be empirically modelled. For each current step a model needs to be determined – in our case we chose to round the currents given before and after the current change to the nearest integer milliampére in order to keep the number of models manageable. With these models a time-series of spikes evoked by magnetic torquer current changes can be computed. The computed time-series can be used to reduce these spikes in accelerometer (cf. section 4).

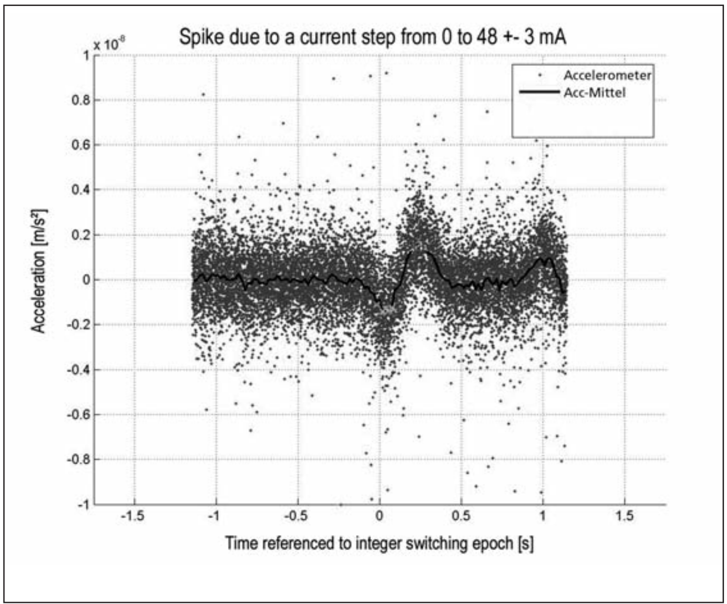

Figure 1: Spike in along track accelerometer data due to current change from 0 to 48 mA in magnetic torquer 1 (*Peterseim 2010*).

Figure 1 shows an accelerometer signal of GRACE A concerning to a typical current step in magnetic torquer 1 (oriented along track) from 0 to 48 mA. The red dots are the superimposed accelerometer data referenced to the integer switching epoch given in the magnetic torquer data. A spike typically consists of two peaks, whereas the order is reversed for negative current changes.

3. Characterisation of twangs

As the cause for the occurrence of twangs is not known up to now, we began our study of these accelerometer spikes by a characterisation of their signal form and their spatial and temporal occurrence.

We identify a twang in accelerometer data by computing the ration of the RMS of a 10s interval in accelerometer data with the RMS of the following 10s interval. If the ratio exceeds a set threshold, which is 1.4 in our case, we assume that there must be a twang in accelerometer data. We proceeded with this approach in 1s steps. Any data that could be affected by thruster activation was not considered as twang.

If a significant time-span of accelerometer data is considered, geographical correlation become obvious (cf. figure 2). Furthermore either the season, the local time, the orbit, or all have a significant impact onto the distribution of twangs. In figure 2, the twangs as occurring in the winter months of 2008 (January, February, November and December) at GRACE B are shown. Geographical correlations, and some correlation with earth magnetic field in the northern hemisphere, are obvious. The red dots are twangs where the first peak is negative, the white dots are twangs where the first peak is positive. Some signatures, with respect to the orientation of the first peak of the spike, appear to be distinct and clearly separated from each other. Here it is already obvious that there are different types of twangs involved, which can be correlated to the spatial occurrence.

Investigation concerning the correlation, distribution and origin of twangs are still ongoing.

4. Level 1 processing alternative

In this part of the project, we want to answer the questions which amplitudes and frequencies of these effects mentioned in the previous sections remain after the pre-processing and filtering applied in the Level 1 accelerometer processing (*Wu et al. 2006*), and whether the remaining amplitudes affect the gravity field results.

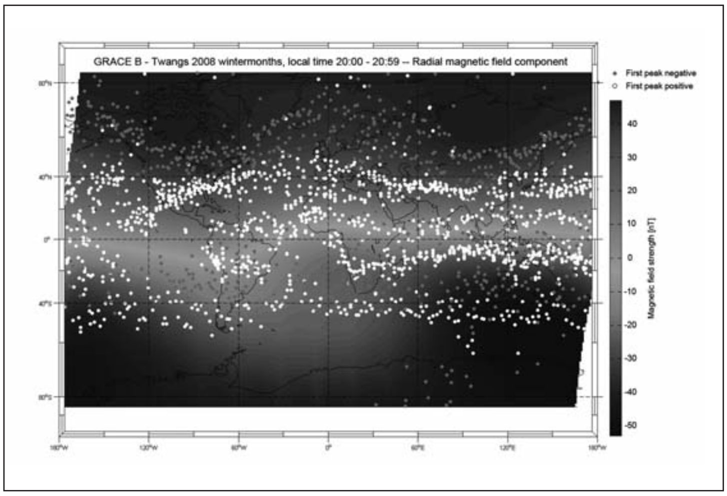

Figure 2: Twangs in winter 2008 in GRACE B vs. radial component of magnetic field of earth determined by GRACE onboard magnetometer.

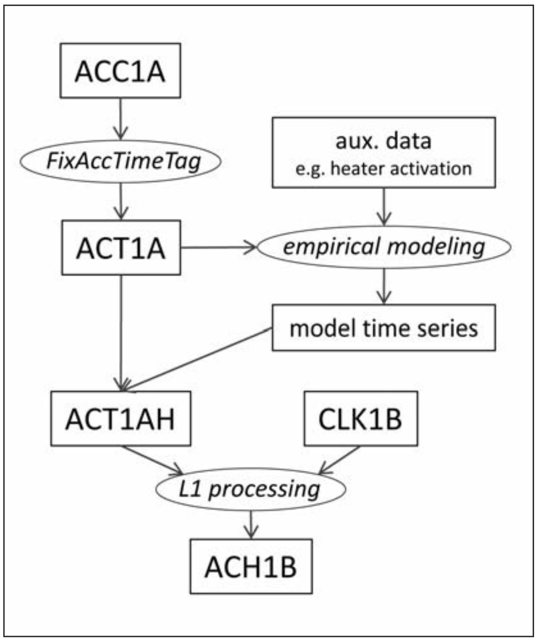

Figure 3: Modified Level 1accelerometer data processing sequence taking into account empirically modelled time series of satellite-induced effects.

The general method is the following (see Fig. 3): we take effects for which empirical modeling at the epochs of 10 Hz Level 1a accelerometer data is available. The modeling results are subtracted from a time-tag corrected intermediate Level 1A product named ACT1A (*Kruizinga 2010*). Then, Level 1 processing is applied to the reduced data using software described in *Frommknecht et al. (2006)*, see also *Frommknecht and Schlicht (2010)*. The resulting alternative Level 1b accelerometer data are examined, and introduced in the gravity field estimation process.

To date, the procedure has been applied to compute Level 1b accelerometer data reduced for heater switching spikes for a period of 4 months (January to April 2008). Results are named ACH1B data. An example of a short time series is shown in Fig. 4.

5. Conclusion

We are now able to provide an alternative accelerometer level 1B dataset were the heater spikes are eliminated. As soon as the modelling of the accelerometer signals due to current changes in the magnetic torquer on GRACE B is done a dataset with reduced magnetic torquer spikes can be prepared.

Furthermore, we showed that the spatial distribution of twangs appear to follow significant patterns, which vary with respect to the local time and season or orbit. Once the cause for some or all twangs is known, depending on how many types of twangs can be clearly identified and associated, it might be possible to model some twangs. The models can then be used like the models in accelerometer data for spikes due to heater and magnetic torquer switching events.

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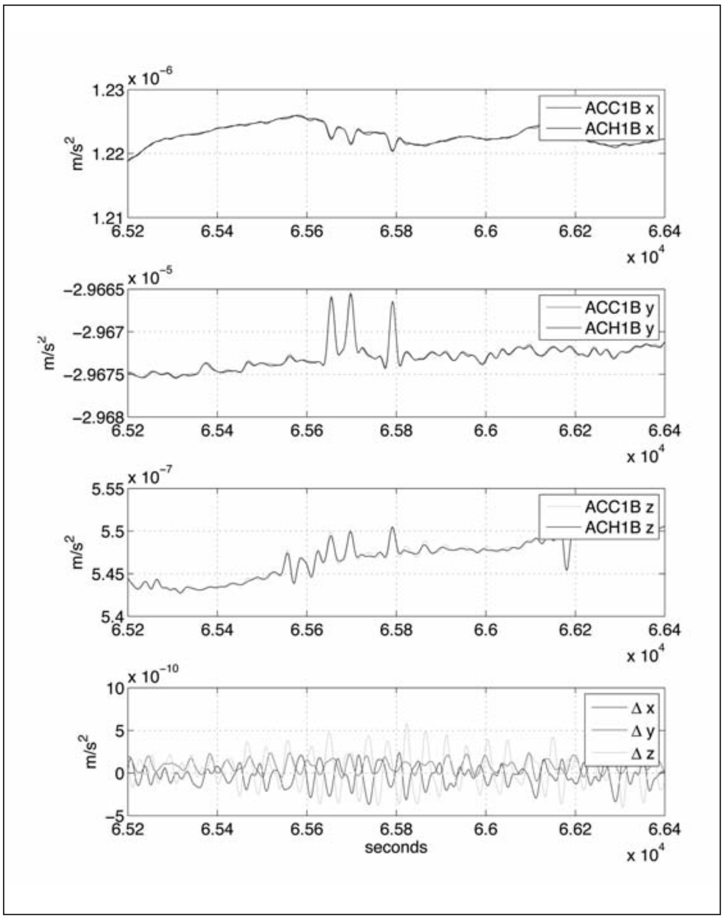

Figure 4: ACH1B acceleration data obtained by reducing heater switching spikes are smoother than the original ACC1B data. The upper three panels show the three accelerometer axes, referring to Science Reference Frame. Differences ACH1B-ACC1B (bottom panel) are typically up to $5x10^{-10}$ m/s^2. The larger peaks in the middle of the example time series are due to thruster activations. Data are from GRACE A, 2007-07-15

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