National Aeronautics and Space Administration

Improved GRACE Accelerometer data transplant due to thruster spike modeling

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ACCELEROMETER DATA STATUS

★ Accelerometer (ACC) on GRACE-B turned off since September 2016 to reduce battery load

★ **Problem:** ACC data from both spacecraft necessary for the gravity field recovery

★ **Solution: ACC data transplant**, i.e. using GRACE-A ACC measurement to generate the missing GRACE-B ACC data

★ ACC data transplant is possible because:

1) both satellites fly in same orbit and the time delay due to the orbit separation is only about 25 s
2) change in the non-gravitational forces within these 25 s is very small, hence both accelerometers should measure approximately the same signal.

★ **Current solution: "simple" ACC data transplant** which includes only time and attitude correction

★ **Updated solution: "full" ACC data transplant** which in addition includes thruster spike modeling

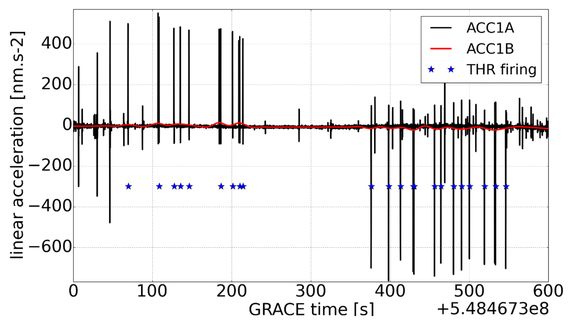
FULL ACC DATA TRANSPLANT

G-A 10 Hz data → *Remove G-A THR spike model* → *Attitude correction* → *Time correction* → *Add G-B THR spike model* → *35 mHz low pass filter* → *G-B transplanted data*

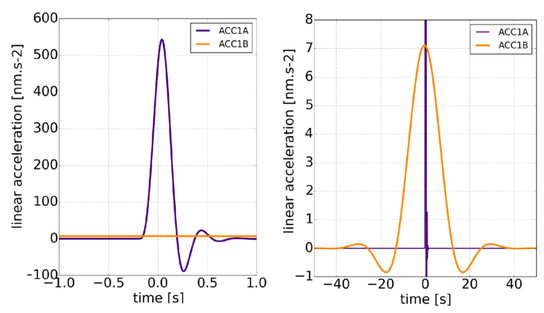
The challenge:

Modeling of residual linear acceleration caused by thruster firings

- There are 12 attitude control thrusters (THR) aboard, operating in pairs, controlling the angular acceleration of the spacecraft
- If the thrusters would be perfect, there will be no linear acceleration sensed by the accelerometer
- **The residual linear accelerations ("thruster spikes") are caused by thruster imperfections such as misalignment of THR pair, force imbalance or differences in reaction time**
- Due to their assymetric shape, the thruster spikes remain in the ACC data even after 35 mHz low-pass filtering
- **The thruster spikes are one of the most dominant high-frequency signals in the ACC measurement**

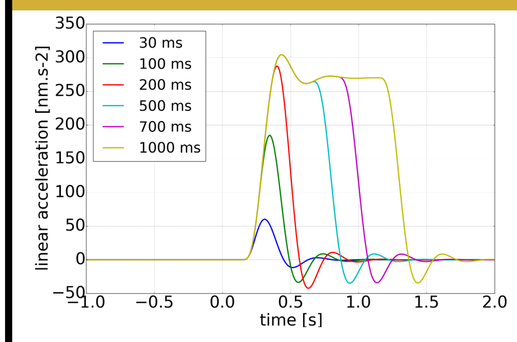


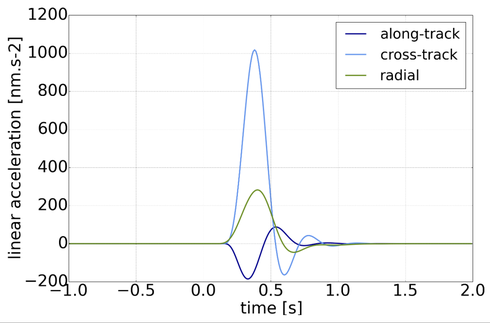
Thruster spikes in linear acceleration (cross-track component) - the original 10 Hz measurement (ACC1A) and the 35 mHz low-pass filtered data (ACC1B).



Thruster spike before and after 35 mHz low pass filter

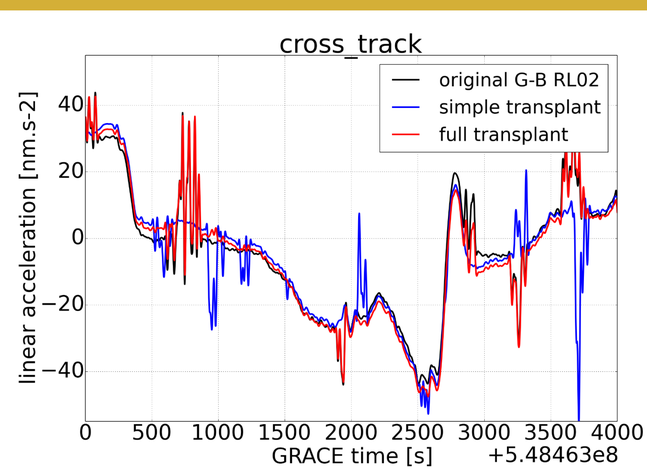
THR SPIKE MODELING





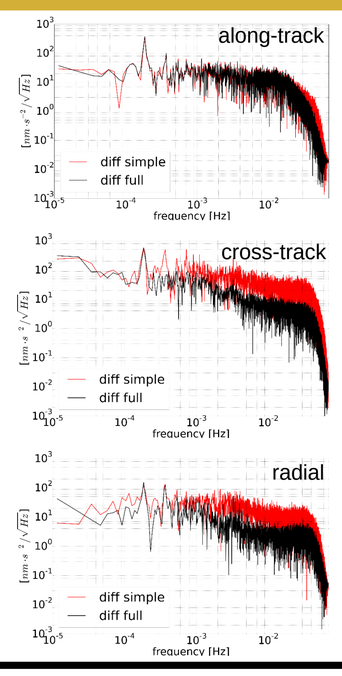
- The thruster spike model is an analytical function obtained by inverse Laplace transform of the ACC transfer function
- The thruster pulse is modeled as two pulse function (ramp shaped + squared pulse)
- The parameters to be estimated using the Least squares method are: amplitude (A_1, A_2) and width (τ_1, τ_2) of the two pulses and ACC response delay (t_0)
- The shape and amplitude of the thruster spikes are unique for each thruster pair, for each firing duration (30 ms – 1000 ms), for each x,y,z component of the ACC linear acceleration, and for each spacecraft, they also depend on other factors such as valve pressure

GRACE-B TRANSPLANTED ACC DATA

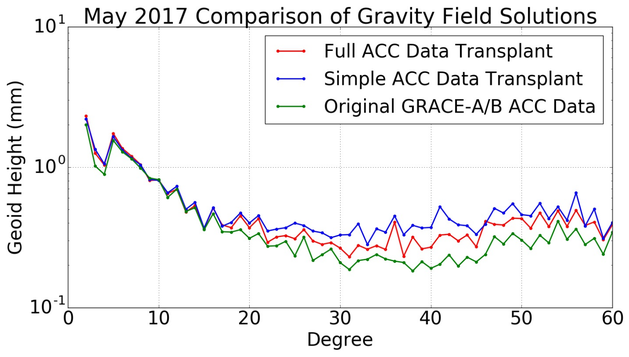


Comparison of the transplanted ACC1B data with the original GRACE-B data for 2017-05-19 (above)

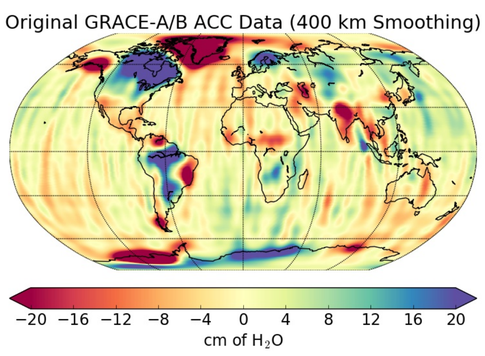
PSD of differences of the transplanted ACC data relative to the original GRACE-B ACC1B data (right)

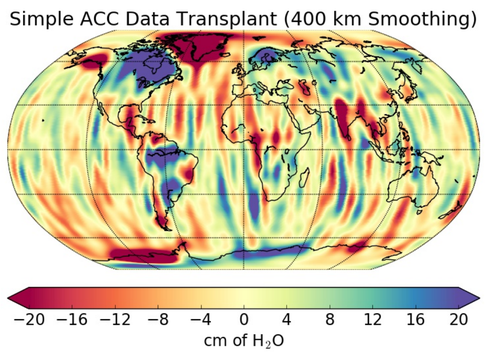


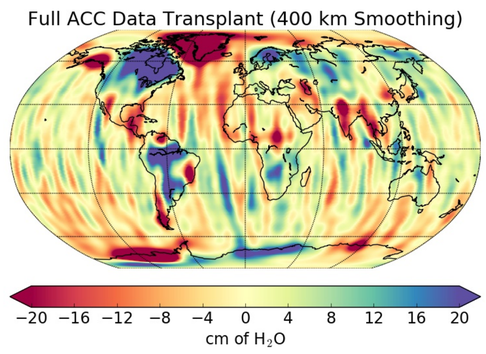
GRAVITY FIELD MODELS FOR MAY 2017



- Comparison of the gravity field solutions in terms of degree variances
- In May 2017 both accelerometers were turned on, which allows validation of the solution
- Full ACC data transplants results in reduced noise for degrees > 18







★ Monthly gravity fields relative to the nominal background field (GIF48), with 400 km Gaussion smoothing radius

★ RMS difference of the transplanted solutions, relative to the 2 ACC solution are:

Simple: 4.94 cm of EWH **Full: 3.92 cm of EWH**

CONCLUSIONS

★ Full ACC data transplant improves the gravity field error by approx. 1 cm of EWH (after smoothing to 400 km) compared to the simple ACC data transplant

★ The data improvement was achieved by reducing ACC high frequency noise caused by residual linear accelerations due to thruster firing

★ The major factor limiting the accuracy of the ACC data transplant is the different attitude of the two spacecraft with respect to the atmosphere

OUTLOOK

⇨ Transplanted ACC data as well as the gravity field solutions to be generated for the following months: Nov 2016 - Apr 2017, Jun 2017

⇨ Further improvement of the THR model needed

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GRACE Science Team Meeting
Austin, TX
Oct 10-12, 2017