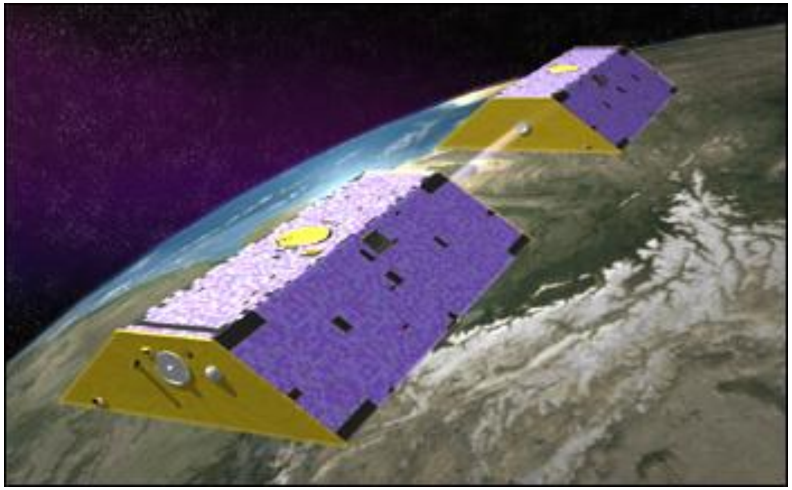
On the accelerometer calibration onboard GRACE

C. Raizner, M. Weigelt, M.G. Sideris

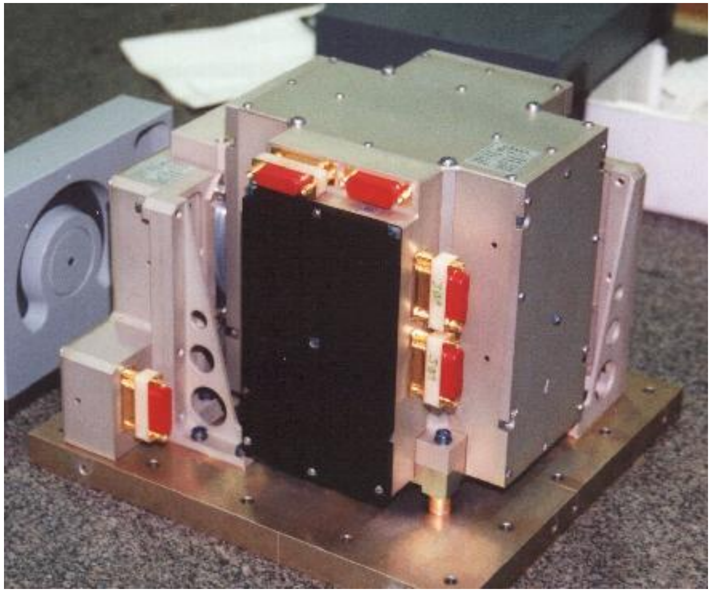
Geomatics Engineering, University of Calgary
mlbweige@ucalgary.ca

Satellite system: GRACE

GRACE = Gravity Recovery and Climate Experiment



- Initial orbit height: ~ 485 km
- Inclination: ~ 89°
- mission duration: 5+ years



- Key technologies:
  - GPS receiver
  - Accelerometer
  - K-Band Ranging System

source: GFZ-Potsdam

Data Processing

- **GPS**
  ⇨ position

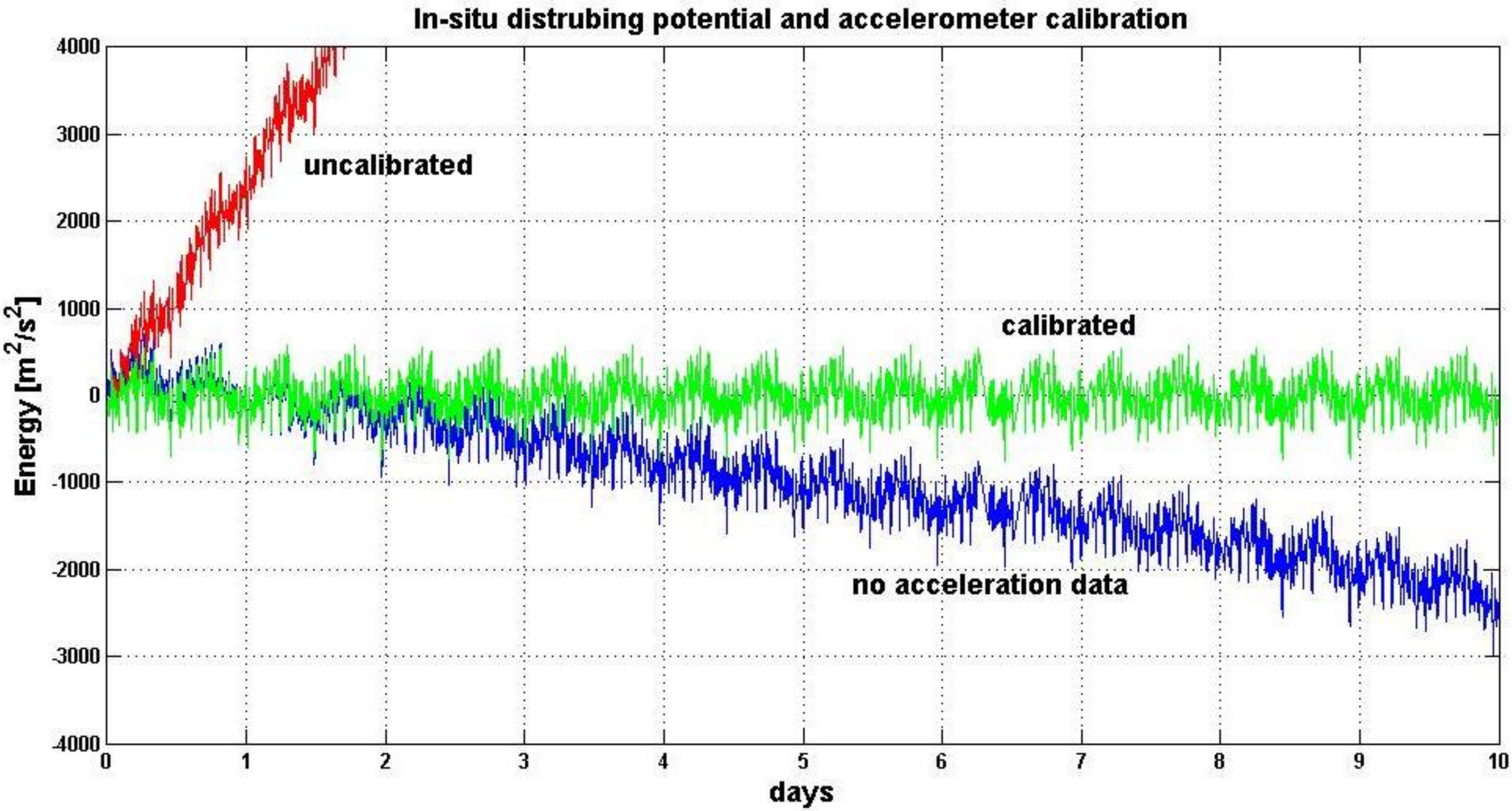
2. **principle of energy conservation**

$$T + c = E_{kin} - U - Z - \int \mathbf{f}\mathbf{dx}$$

  ⇨ gravity field along the orbit

3. **spherical harmonic analysis**

Impact of Accelerometer



Calibration Approach

PROBLEM: accelerometer inaccessible

- comparison to an a-priori model (e.g. EGM96):
  - uncalibrated disturbing potential

$$T + c = E_{kin} - U - Z - \int \mathbf{f}^{\mathbf{m}} d\mathbf{x}$$

  - disturbing potential from a-priori gravity field

$$T_0 = E_{kin} - U - Z - \int \mathbf{f}^{\mathbf{t}} d\mathbf{x}$$

Error Model

true non-gravitational accelerations f^{t}

error model

- bias b
- scale factor s

measured non-gravitational accelerations f^{m}

- simple example: $\mathbf{f}^{\mathbf{t}} = \mathbf{s} \cdot \mathbf{f}^{\mathbf{m}} + \mathbf{b}$
- caution: overmodeling for higher order models

Calibration Steps

comparison to a-priori model
$T-T_0$

energy calibration
⇨ no physical meaning of estimated parameters

accelerometer calibration
⇨ derivation of physical meaningful parameters for each component of acc.

robust least-squares adjustment
(Huber estimator)

estimated parameters

calibrated disturbing potential

Energy Calibration - Models

- approach 1:

$$T - T_0 = -c + d_1 \cdot \Delta t + s \cdot \int \mathbf{f}^{\mathbf{m}} \mathbf{dx}$$

- approach 2:

$$T - T_0 = -c + d_1 \cdot \Delta t + \frac{1}{2} d_2 \cdot \Delta t^2 + s \cdot \int \mathbf{f}^{\mathbf{m}} \mathbf{dx}$$

- approach 3:

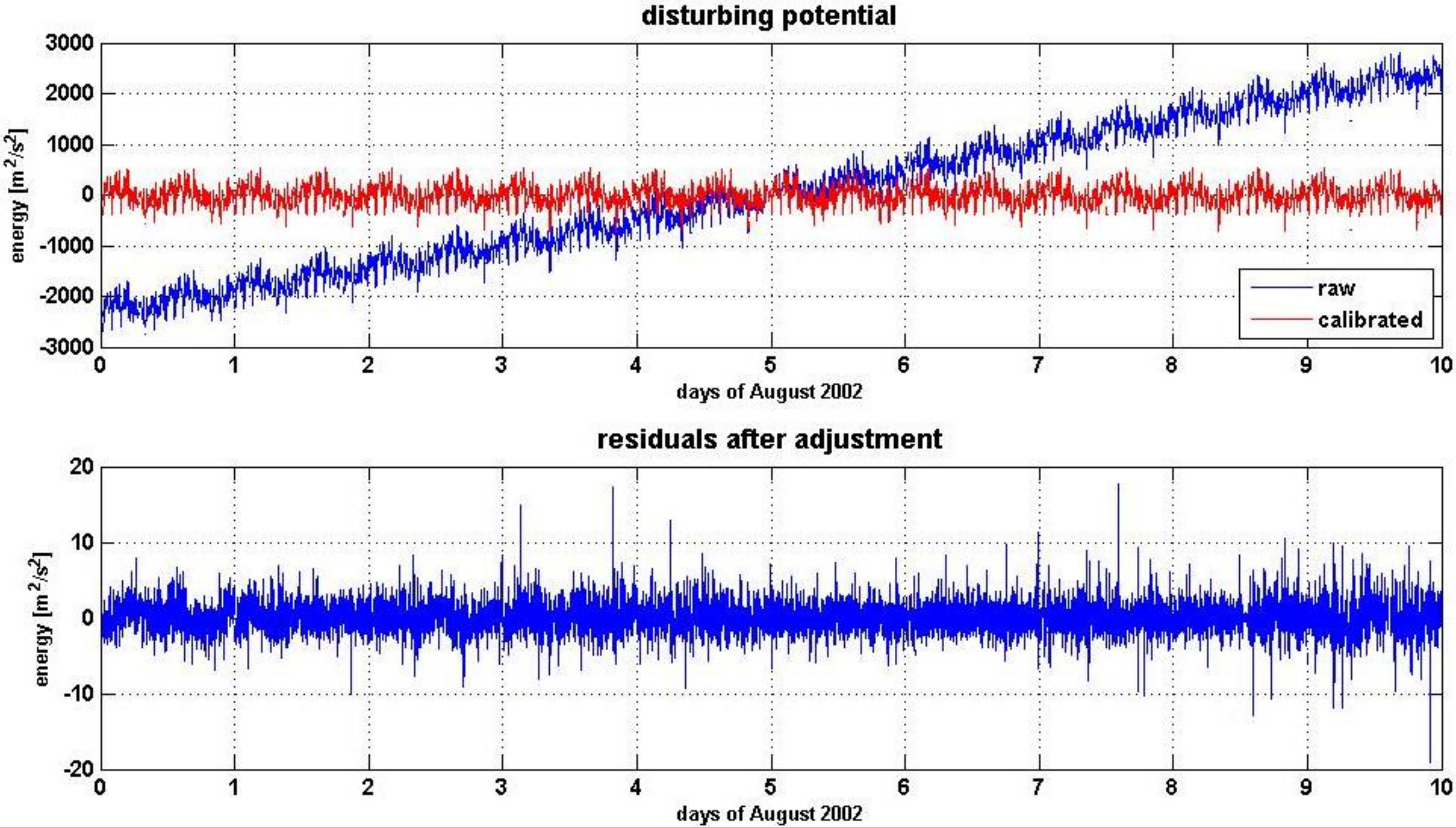
$$T - T_0 = -c + d_1 \cdot \Delta t + \frac{1}{2} d_2 \cdot \Delta t^2 + \frac{1}{6} d_3 \cdot \Delta t^3 + s \cdot \int \mathbf{f}^{\mathbf{m}} \mathbf{dx}$$

- approach 4:

$$T - T_0 = -c + d_1 \cdot \Delta t + \frac{1}{6} d_3 \cdot \Delta t^3 + s \cdot \int \mathbf{f}^{\mathbf{m}} \mathbf{dx}$$

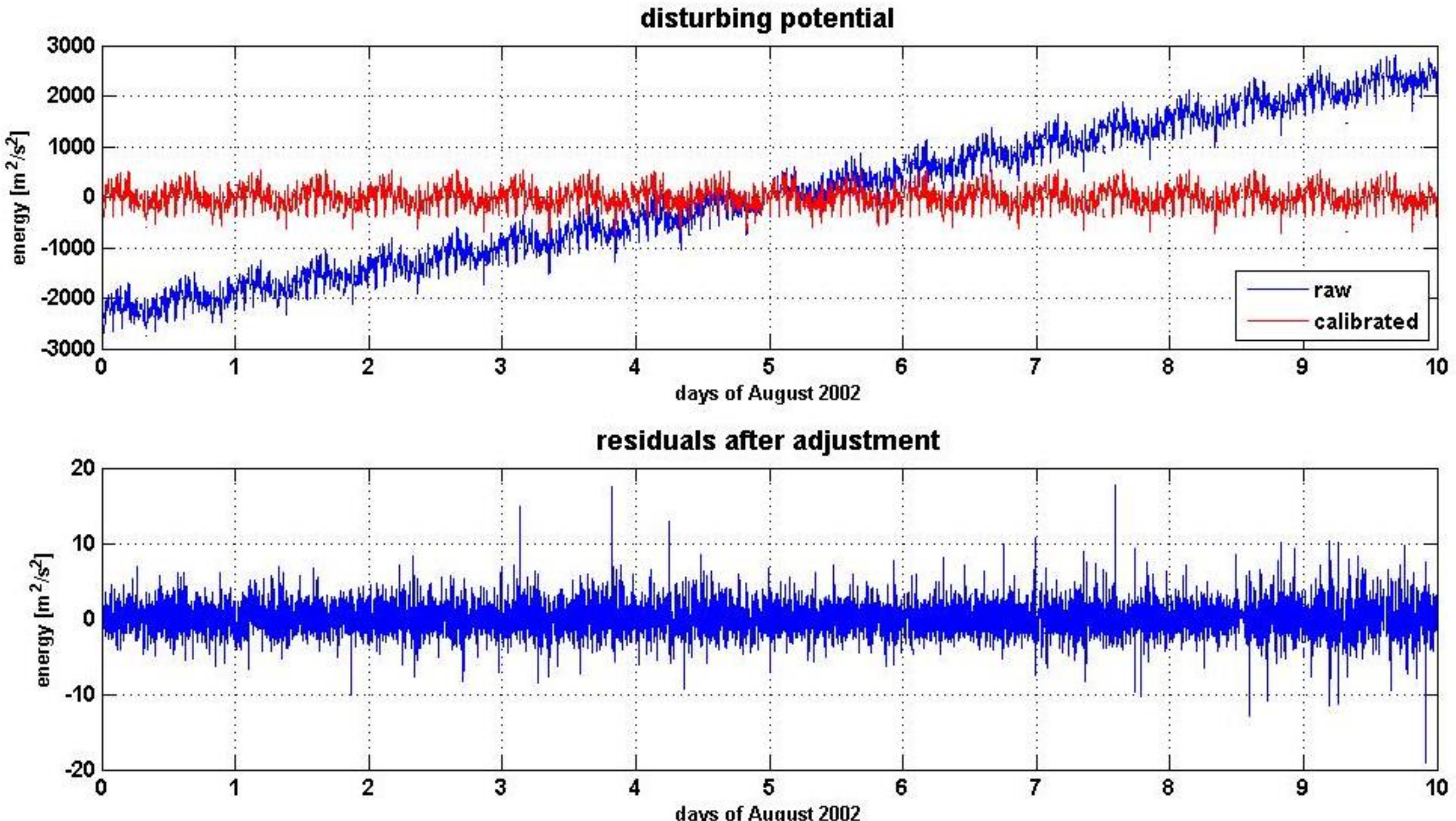
Energy Calibration - Results

approach 1: linear drift



Energy Calibration - Results

approach 2: linear drift + quadratic drift



Energy Calibration - Results

- statistics for differences between calibrated and a-priori disturbing potential

approach	linear drift d_1	quad. drift d_2	cubic drift d_3	scale	mean of Δ	RMS
1	426.9322	-	-	0.0884	0.0050	1.6052
2	206.0507	25.2190	-	0.0444	0.0047	1.5560
3	-1535.5293	382.5055	-36.6489	0.0448	0.0047	1.5566
4	329.0073	-	2.5861	0.0444	0.0047	1.5566

Acceleration Calibration

fixed scale factor!

- approach 1: one bias component for each axis once per day

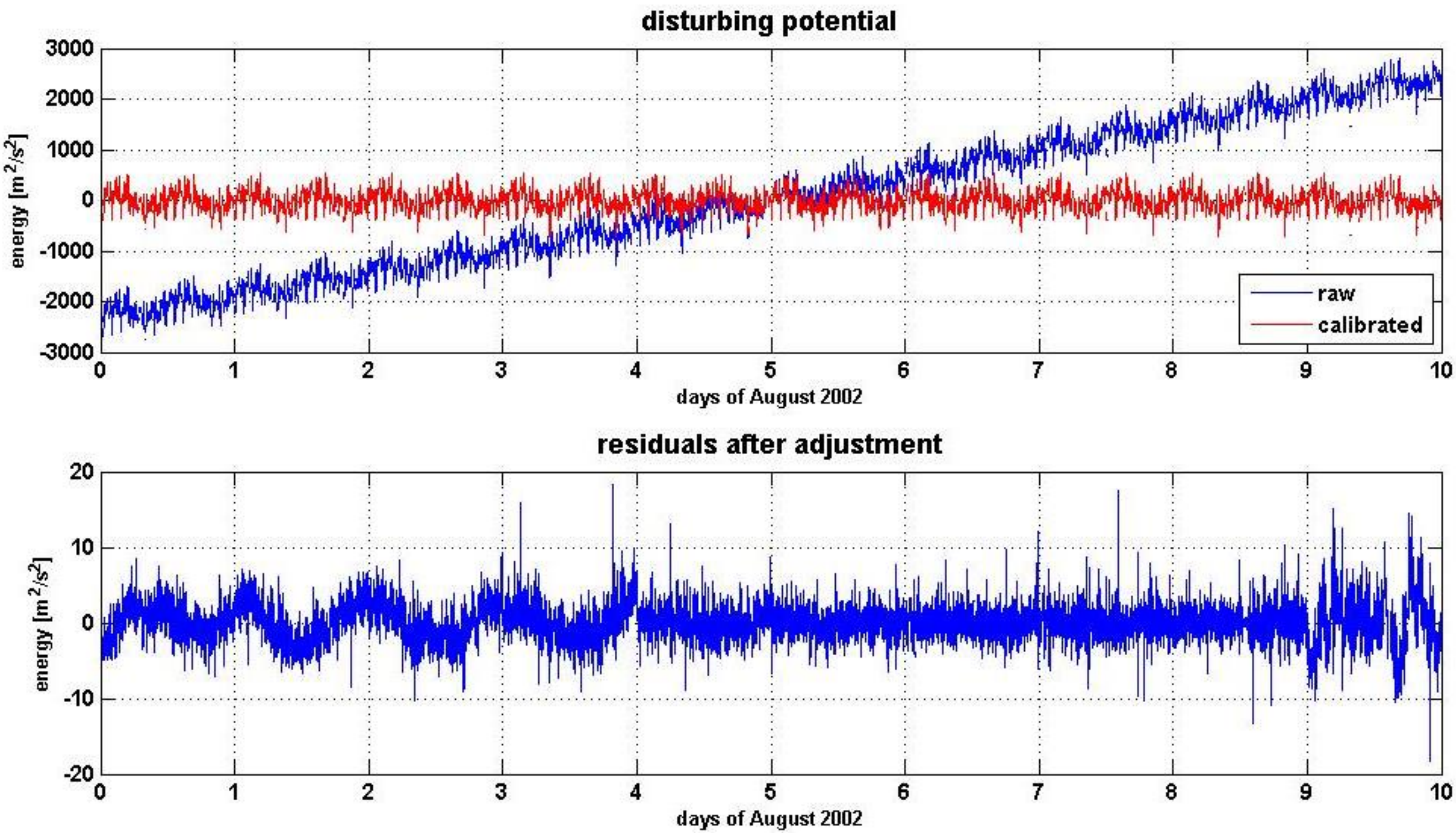
$$T - T_0 = -c + b_x \int dx + b_y \int dy + b_z \int dz$$

- approach 2: one bias and one drift component for each axis once per day

$$T - T_0 = -c + b_x \int dx + b_y \int dy + b_z \int dz + d_x \int \Delta t dx + d_y \int \Delta t dy + d_z \int \Delta t dz$$

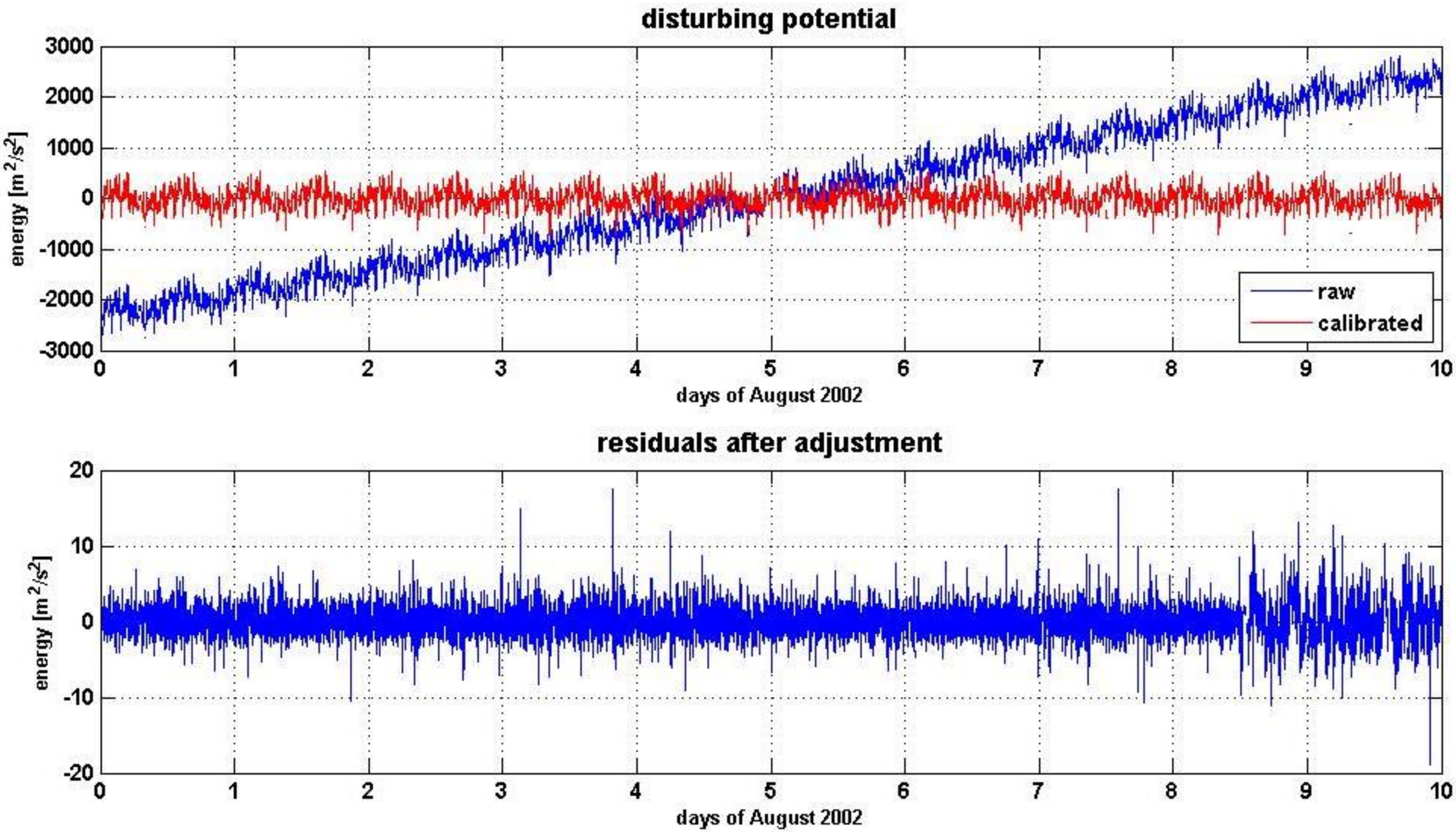
Acceleration Calibration - Results

approach 1: one bias component for each axis once per day



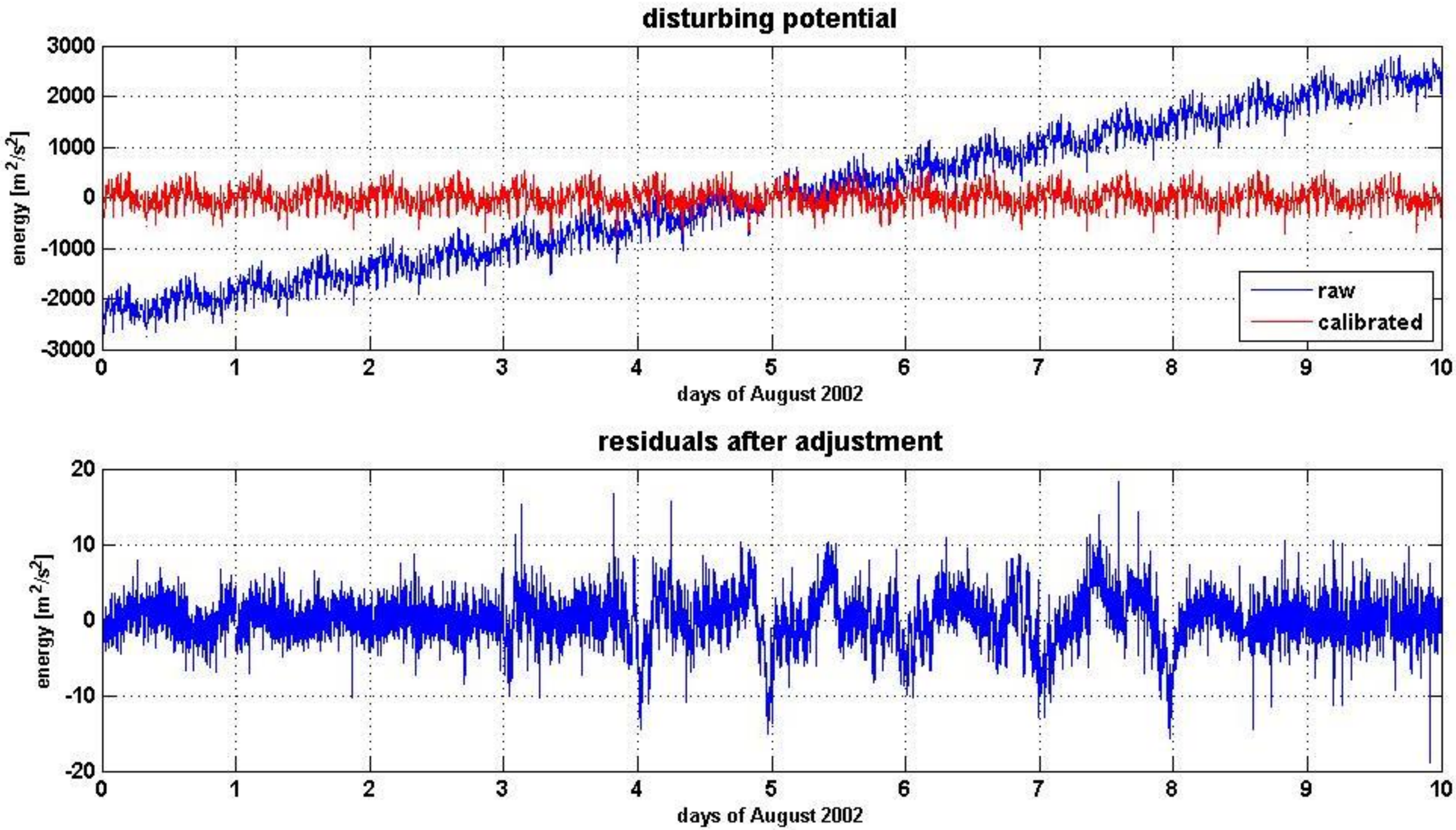
Acceleration Calibration - Results

approach 1: one bias component for each axis 4 times per day



Acceleration Calibration - Results

approach 2: bias and drift model



Conclusion

- successful calibration on energy level
- second order model is recommended
- problem: no physical meaning of the estimated parameters

- calibration on accelerometer level is problematic
- no scale estimation at the moment
- estimated parameters can currently not be interpreted
  ⇨ problem needs further investigation

Questions ?

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