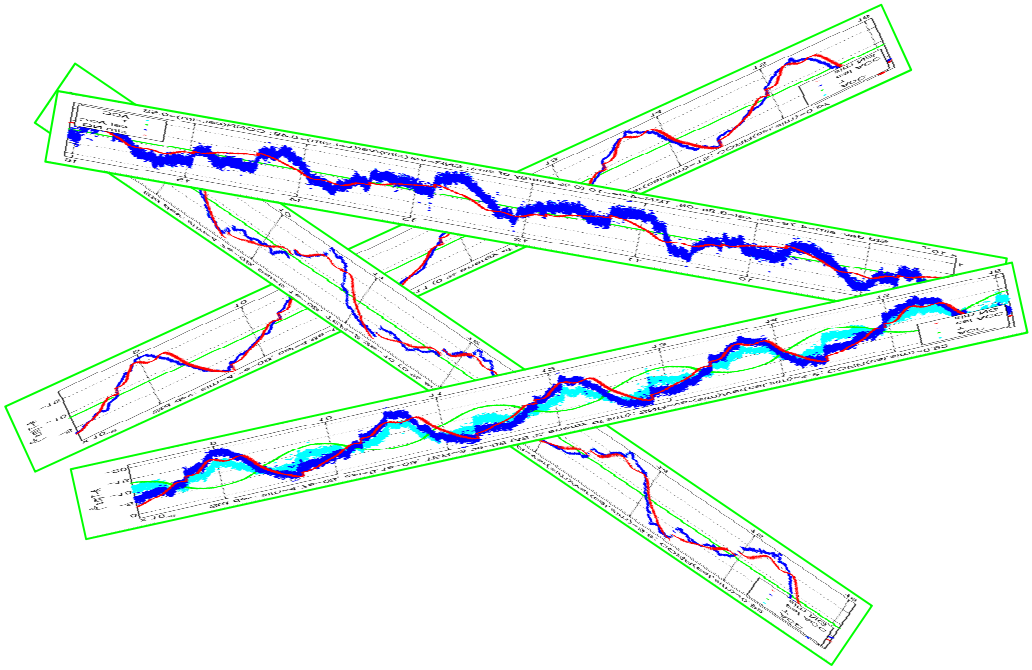
Validation of Swarm ACC preliminary dataset



Aleš Bezděk
Josef Sebera
Jaroslav Klokočník

Astronomical Institute,
Czech Academy of Sciences,
Czech Republic

Swarm 5th Data Quality Workshop,
Institut de Physique du Globe de Paris,
France, 7 – 10 September 2015

ACC test data sets & SIM-validation

ACC test data sets TDS1, TDS2:

- calibrated along-track accelerations of Swarm C (Jun – Dec 2014)

(1) corrected for steps (except for three weeks in Oct–Nov)

(2) free from temperature effects

(3) adjusted to POD-derived accelerations

- correction (1) is the same for both TDS1 & TDS2, corrections (2)–(3) are different

SIM-validation

- ACC waveform is compared with simulated physical nongravitational (NG) signal
- To the comparison optionally the temperature variation signal can be added

SIM-validated arcs are defined:

- good agreement of (un)corrected ACC waveform with physical NG signal
- quantitatively: orbital arcs having high CORR(ACC,NG) and low RMS (std. error of the fit)

So far with Swarm ACC data, two basic reasons manifested for an arc **not** to be SIM-validated:

(A) arcs with substantial ACC anomalies (steps, jumps, spikes, …)

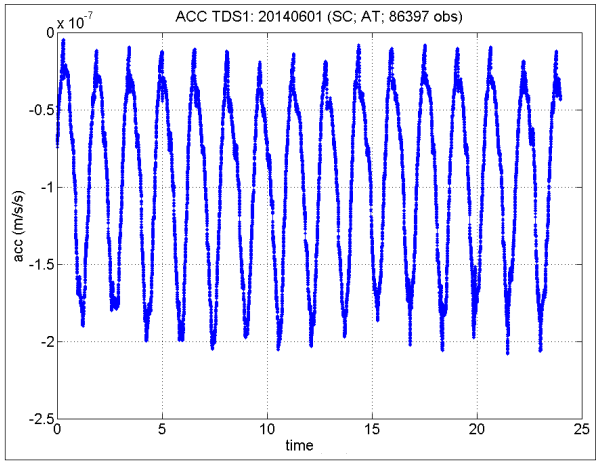
(B) arcs with important temperature dependence (Swarm A/B, Swarm C less)

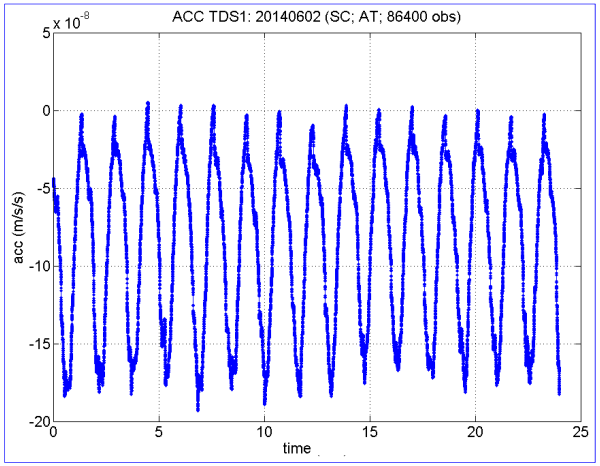
Aim of this presentation: validate properties (1), (2) of TDS1, TDS2

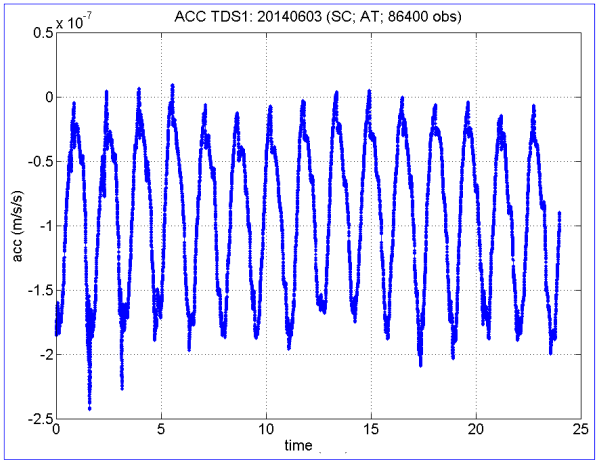
ACC test data sets: quick look comparison

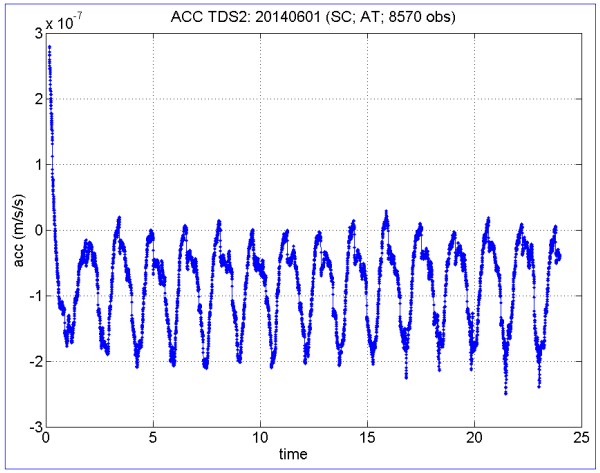
Example figures: daily files 1–3 June 2014

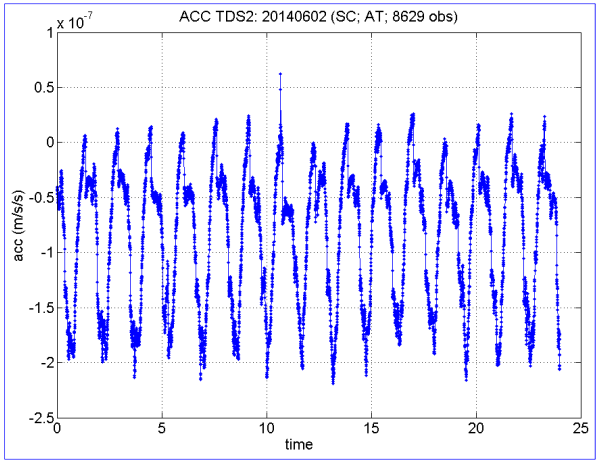
- TDS1 (first row): time step 1 sec, smoother compared to TDS2
- TDS2 (second row): time step 10 sec; sometimes possible outliers

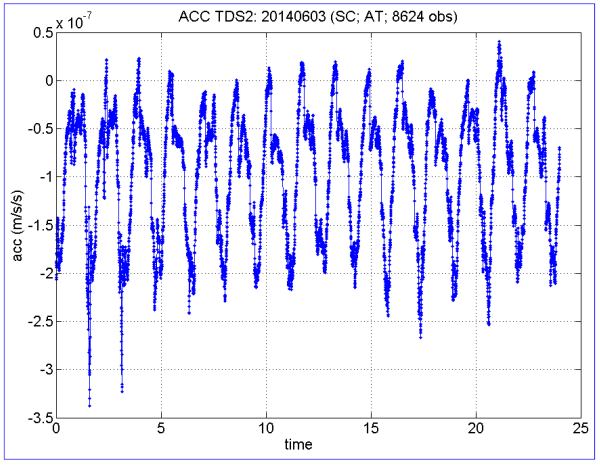












ACC test data sets: correction of steps

Figures:

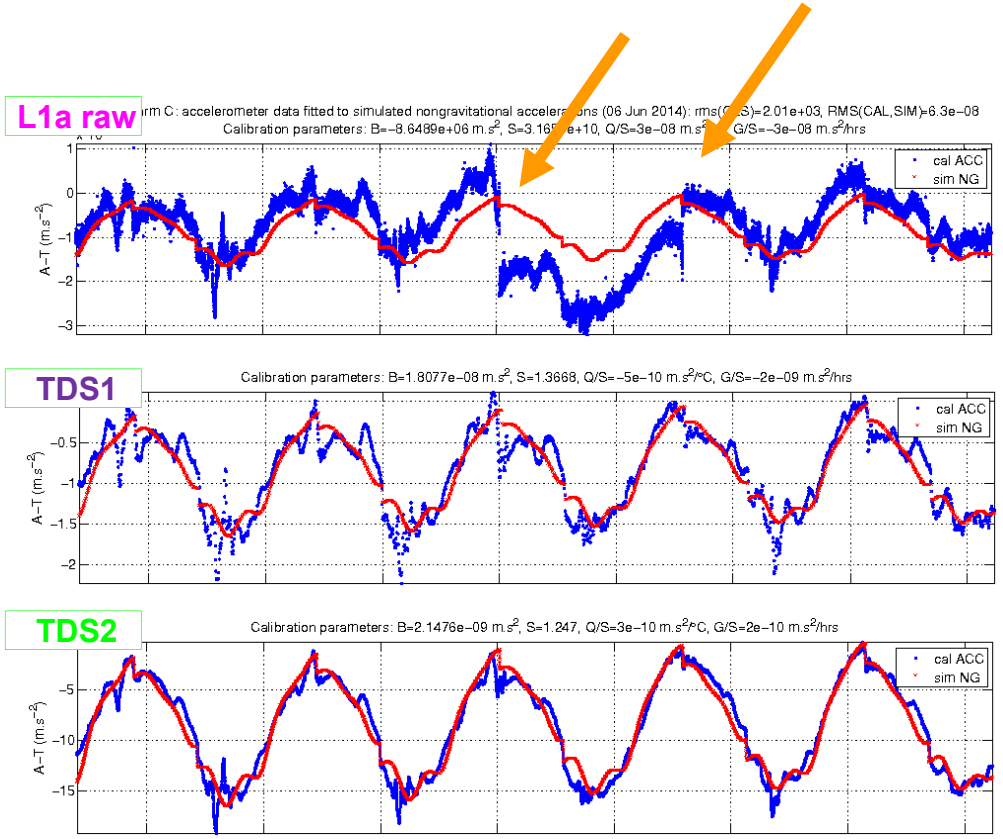
- Swarm C, 6 Jun 2014, along-track component, orbital arc of 5 revolutions
- ACC data (blue)
- physical NG signal (red): ACC should produce approximately this waveform

Upper fig: **L1a raw** ACC data

- example of step-like anomalies

Lower figures: test data sets

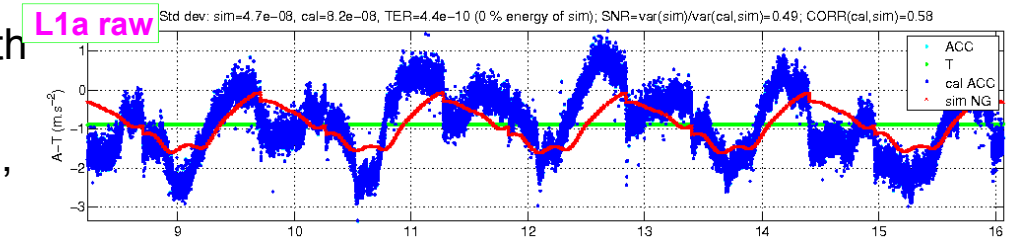
- both **TDS1**, **TDS2** corrected for steps



SIM-validation of ACC L1A data

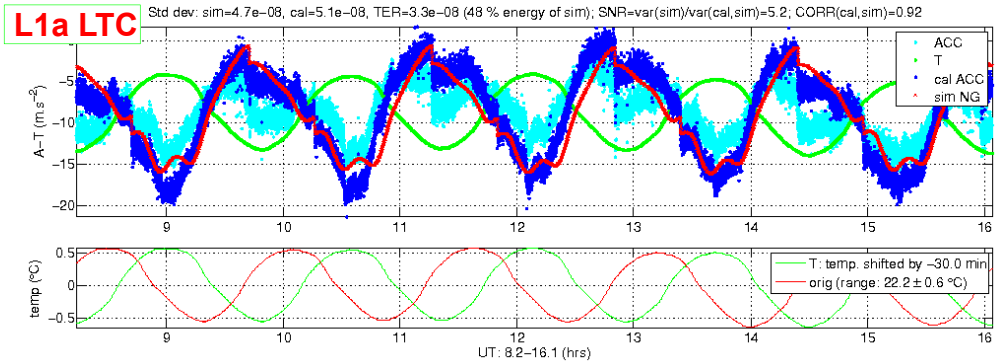
Validation of ACC data by comparison with simulated nongravitational signal

- Typical example: Swarm C, 1 Jun 2014, along-track component, 5 revolutions



Upper fig: **L1a raw** (no temperature corr)

- ACC readouts (blue)
- physical NG signal (red)
- coefficient of correlation: corr=0.58



Lower figure: **L1a LTC** (temperature corrected)

- ACC readouts (cyan)
- linear temperature correction (LTC): fitted temperature (green); phase shift –30 min
- fitted ACC signal (blue)
- coefficient of correlation: corr=0.92

Application of linear temperature correction (LTC) substantially improves correlation of corrected ACC data with physical nongravitational accelerations.

SIM-validation of ACC data: L1a, TDS1, TDS2

Validation of ACC data by comparison with simulated nongravitational signal

- physical NG signal (red)
- fitted ACC/TDS signal (blue)
- optionally fitted temperature (green)

Orbital arc: Swarm C, 1 Jun 2014, along-track component, 5 revolutions

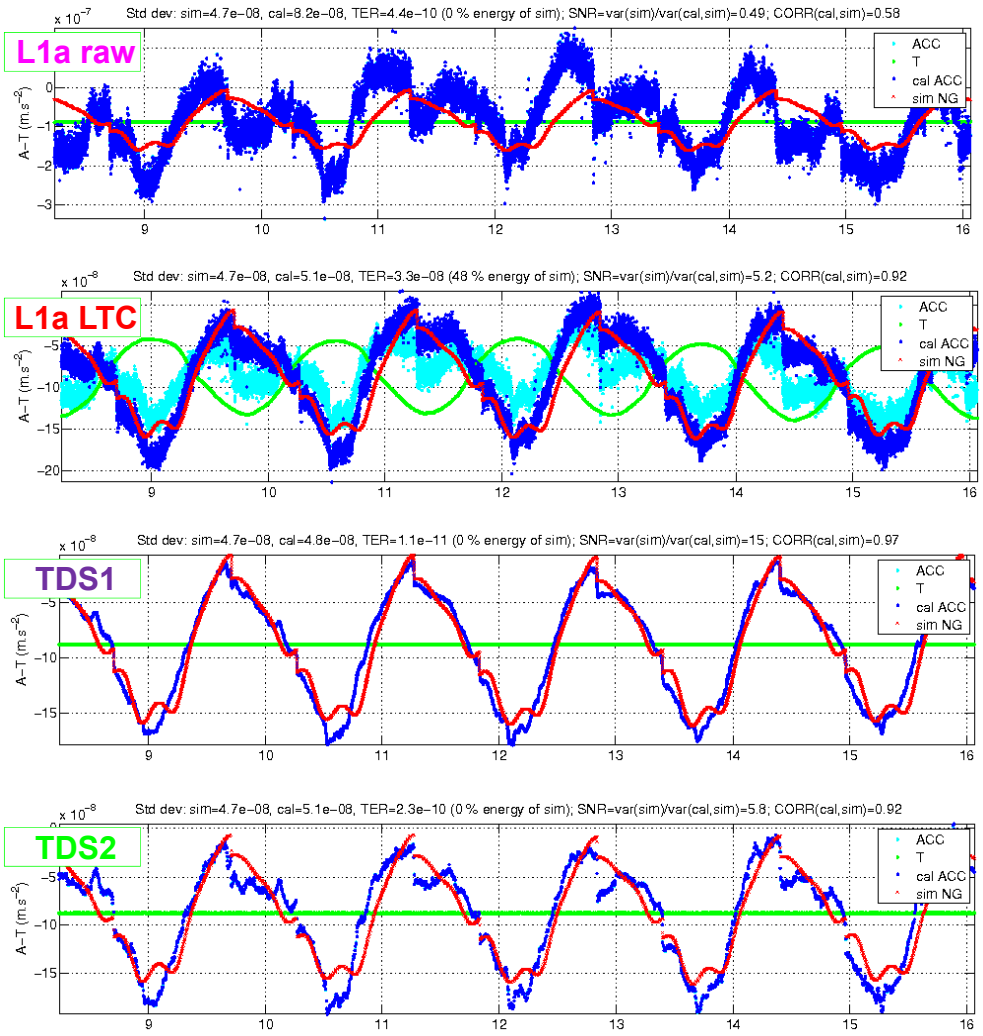
Figures and results for ACC data:

L1a raw: corr=0.58

L1a LTC: corr=0.92

TDS1: corr=0.97

TDS2: corr=0.92



In this example block, all temperature corrections (LTC, TDS1, TDS2) substantially improve correlation of corrected ACC data with physical nongravitational accelerations.

Is this a typical behaviour for the whole test period of 6 months?

Increase in #SIM-validated arcs for corrected ACC data

Figures:

- Data: Swarm C, A-T component, Jun-Dec 2014
- Correlation coefficient between ACC data and NG models for each arc (5 revolutions)
- SIM-validated arcs (in red): corr>0.85

Percentage of SIM-validated arcs:

L1a raw: 50 %

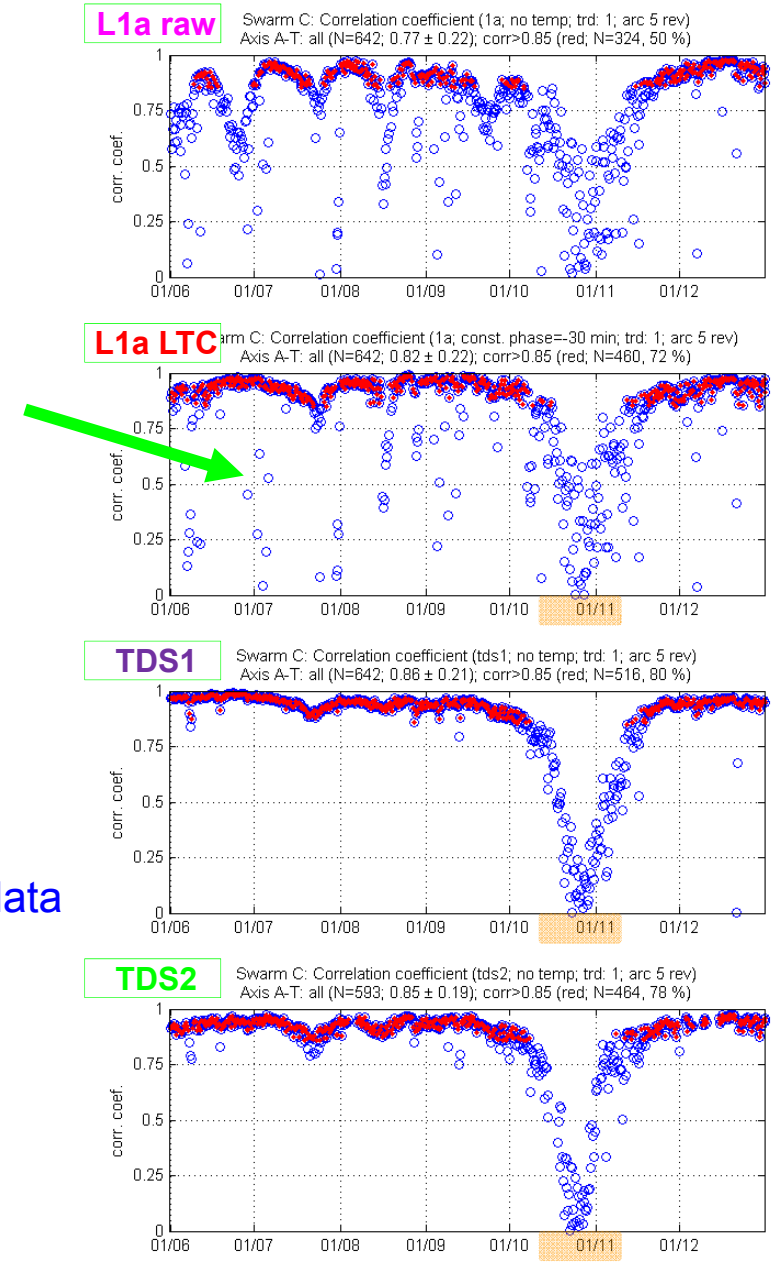
L1a LTC: 72 %

TDS1: 80 %

TDS2: 78 %

Results:

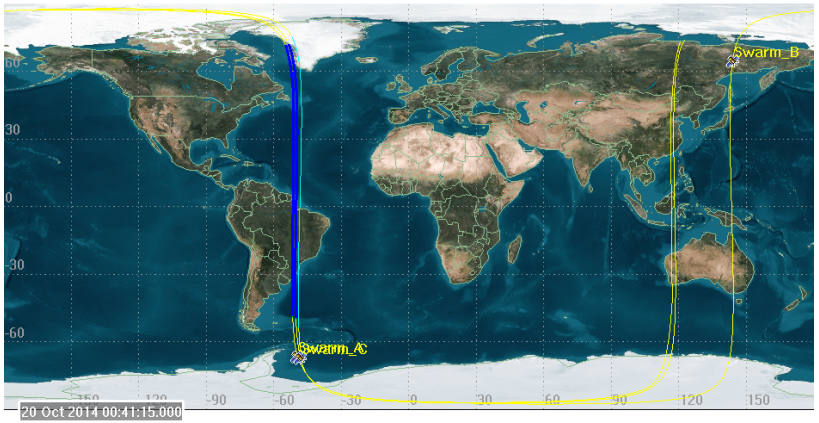
- all temperature corrections (LTC, TDS1, TDS2) substantially improve correlation of corrected ACC data with NG models
- problematic 3-week period Oct-Nov 2014 of ACC observations present in all corrected data sets
- LTC-corrected data contain arcs with steps, which were amended in TDS1, TDS2



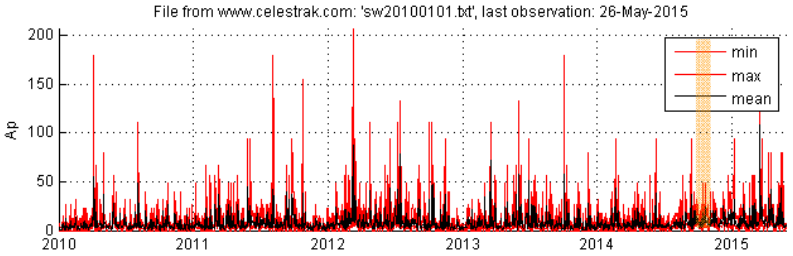
Raw ACC data: problematic 3-week period Oct-Nov 2014

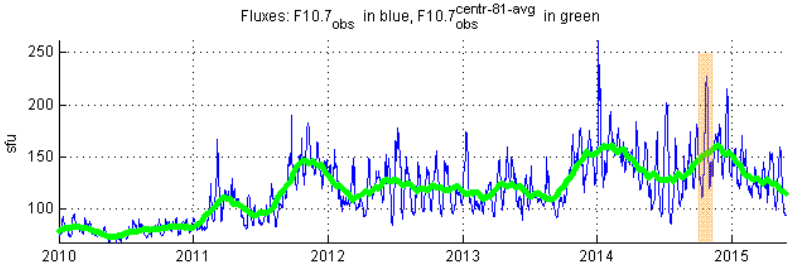
Peculiarity in TDS1, TDS2 (and LTC data as well):

From mid of October to beginning of November 2014, a very large number of steps occurred, which we were not able to correct reliably. Because the net effect of these steps was found to be close to zero, we decided not to correct for them.



In any case, we tried to find something special in orbital or physical conditions, etc.





Orbital conditions

- pair of Swarm A/C going side-by-side (at 458 km)
- orbit of Swarm B (at 505 km) not so far from that of Swarm A/C

Solar activity

- slight increase over Jun-Dec 2014
- nothing special in Oct-Nov

What about the onboard temperature?

Raw ACC data: problematic 3-week period Oct-Nov 2014

Onboard temperature

- Since 15 Oct 2014, mean onboard temperature (blue) started to rise (increase by about 3 °C)
- daily variations (green) are about the same
- similar behaviour for all Swarm A/B/C satellites

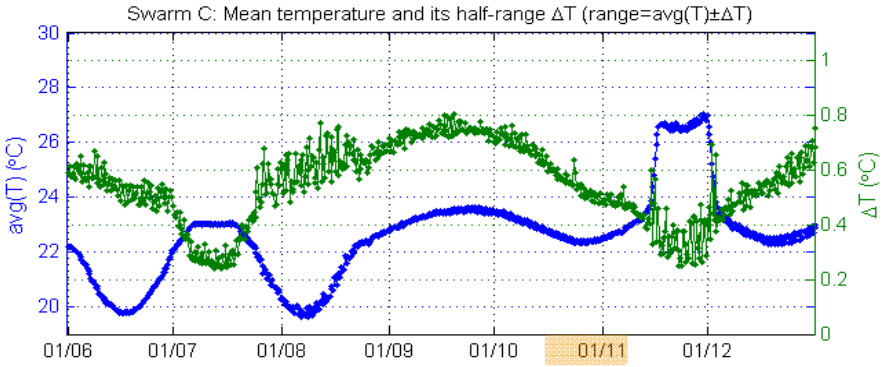
Increase in mean onboard temperature

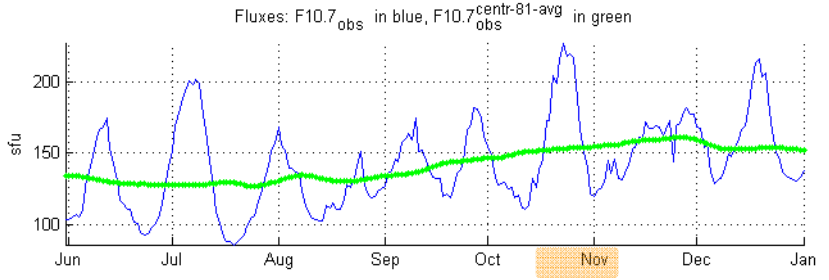
- probably due to higher solar flux (middle fig)

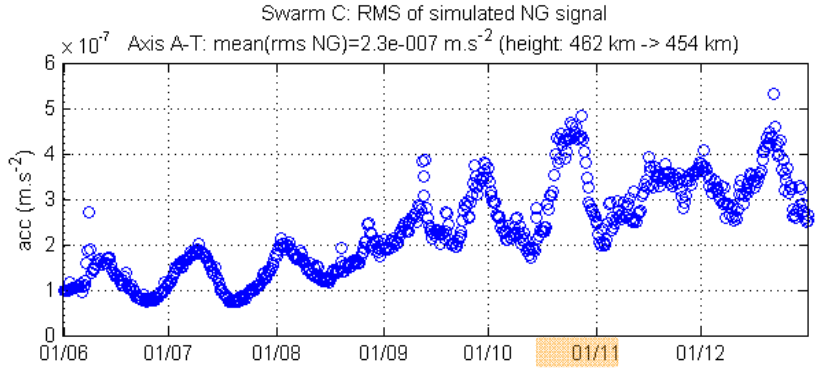
Variations in solar flux

- mean solar flux increasing
- simulated NG acceleration in A-T increasing (bottom fig)

What about ACC data on other Swarm satellites?







Raw ACC data: problematic 3-week period Oct-Nov 2014

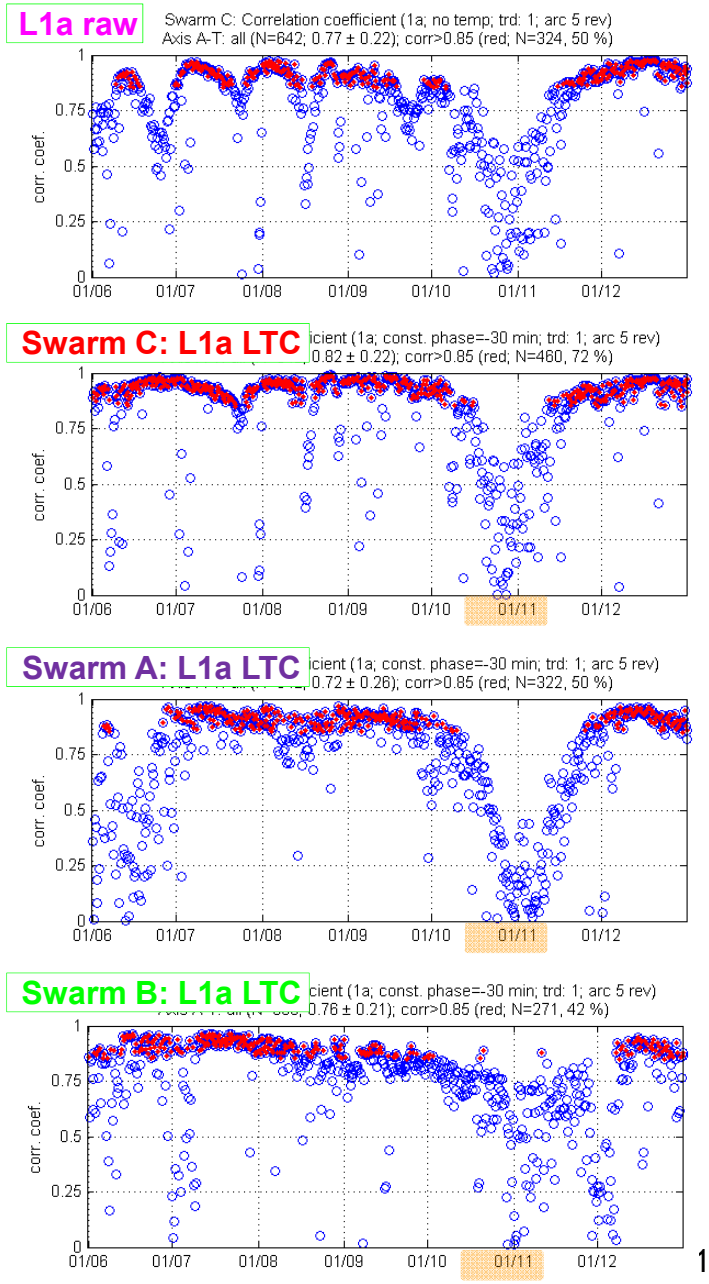
Similar problems with ACC raw data <u>experienced by accelerometers on Swarm A and Swarm C</u>

- to a lesser extent by ACC on Swarm B
- Swarm A/C flying side-by-side, accelerometers are independent pieces of hardware

  → <u>Common cause of this ACC behaviour?</u>

A possible cause was found:

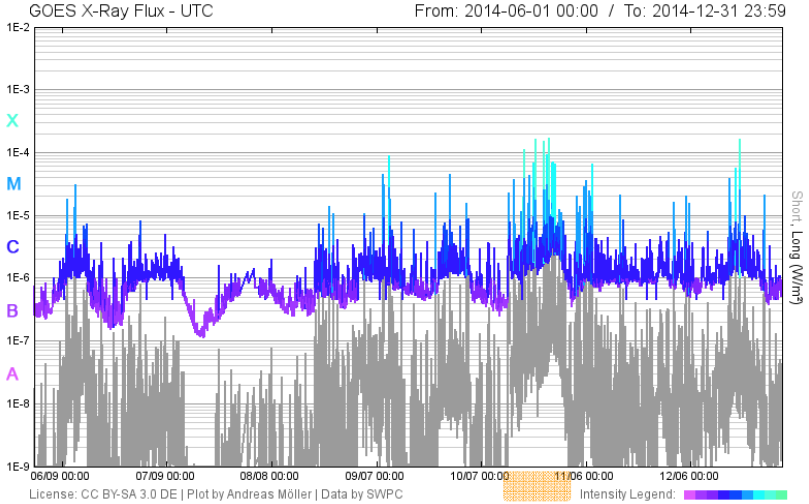
- series of strong solar flares in second half of Oct 2014



Raw ACC data: problematic 3-week period Oct-Nov 2014

A possible cause for these problems might be:

Strong solar flares in second half of October 2014

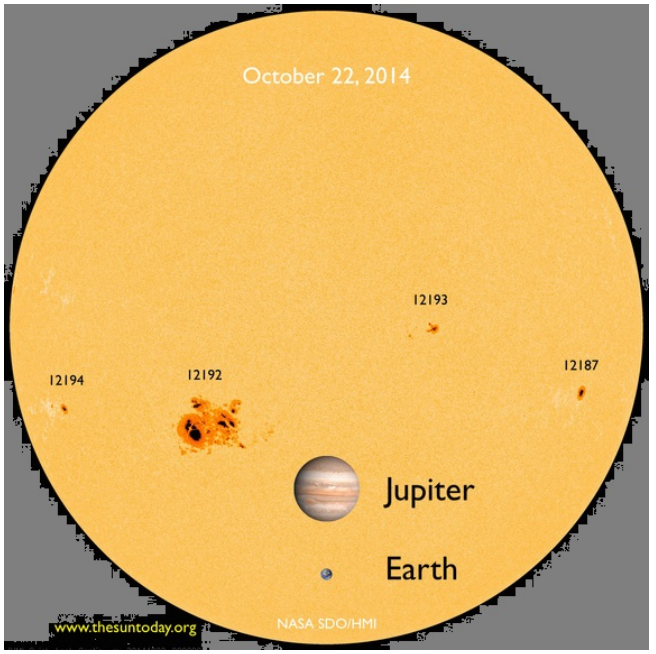


Solar flares

- produce electromagnetic radiation across the electromagnetic spectrum at all wavelengths
- occur mostly around sunspots

Active region AR 12192

- largest in 24 years
- fired off 10 sizable solar flares
- did not produce any significant coronal mass ejections
- between 19 and 28 Oct it produced six X-class flares (largest flares) and four strong M-class flares



http://www.nasa.gov/content/goddard/tracking-a-gigantic-sunspot-across-the-sun/

This is just an idea for discussion…

Conclusions: feedback on TDS1, TDS2

ACC test data sets TDS1, TDS2: Swarm C, A-T component, Jun – Dec 2014

Quick-look comparison of TDS1, TDS2 signal:

- TDS1 is smoother compared to TDS2
- TDS2 may sometimes contain outliers

SIM-validation: comparing waveforms of ACC data and modelled physical signal

For the whole 6-month period except three weeks in October:

- both TDS1, TDS2 clearly removed steps present in raw ACC data
- both TDS1, TDS2 temperature corrections substantially improve correlation of the two waveforms, final correlations are larger than 0.9

Problematic 3-week period Oct-Nov 2014:

- similar problems in raw ACC data of Swarm A and Swarm C → possible common cause
- nothing special in orbital and physical conditions
- for discussion: series of strong solar flares in second half of October 2014

Thank you for your attention