Swarm Level 2 accelerometer data processing

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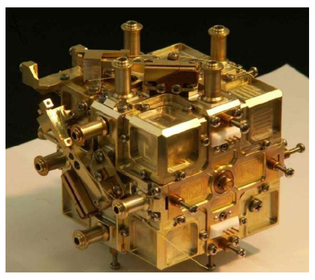
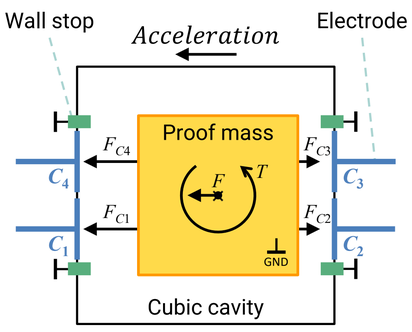
Introduction

The accelerometer measures the satellite's non-gravitational accelerations, needed to derive the neutral density of the thermosphere. Its principle of operation is based on the electrostatic compensation of the proof mass motion with respect to the cavity, rigidly fixed close to the spacecraft's center of gravity. Since the raw accelerations are heavily distorted with various anomalies, the Level 1B accelerations are not available to the public. Consequently, a sophisticated Swarm Level 2 accelerometer data processing was implemented, as briefly summarized in this presentation. As a result, scientifically valuable Swarm Level 2 accelerometer data are released (currently, only for the *x*-axis, which is approximately pointing in the along-track direction).

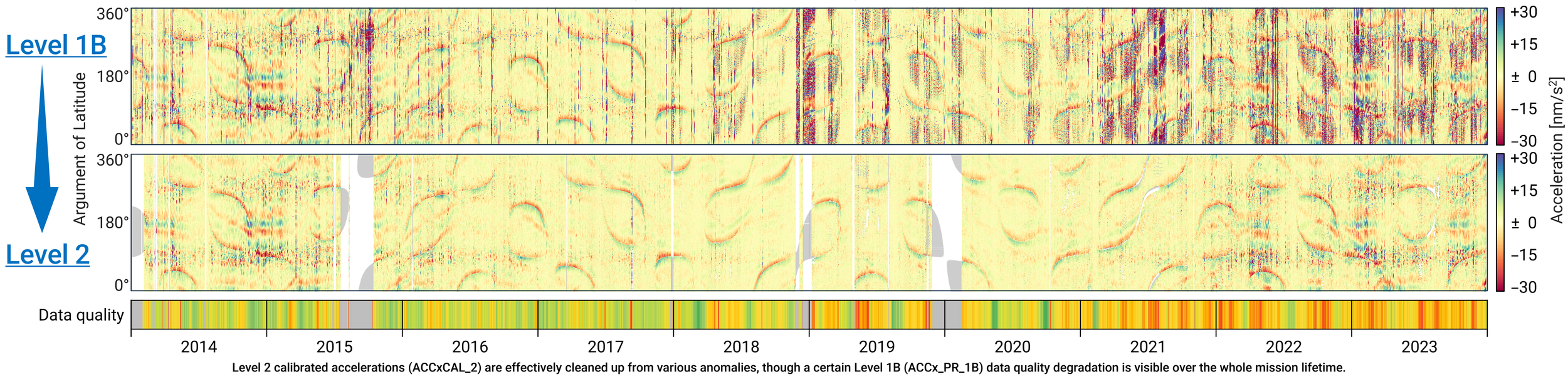
Principle of operation



As the cavity accelerates due to non-gravitational forces and torques acting on the satellite, the feedback system compensates translational and rotational movements of the cubic proof mass depending on the gap-varied capacitors C_1 to C_4. The generated control voltages represent the measured acceleration.



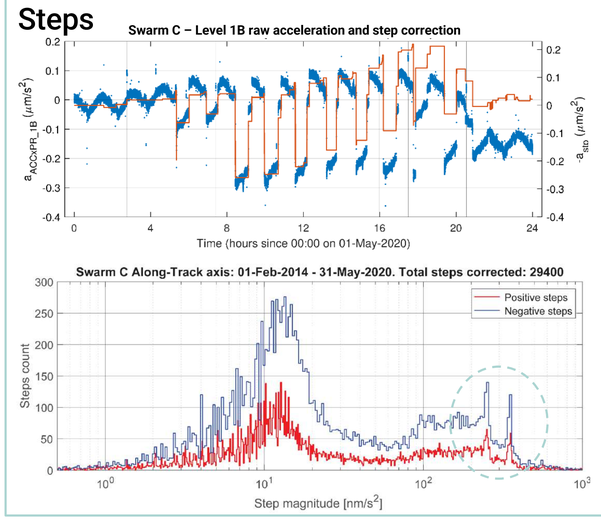
Swarm C high-pass filtered along-track acceleration



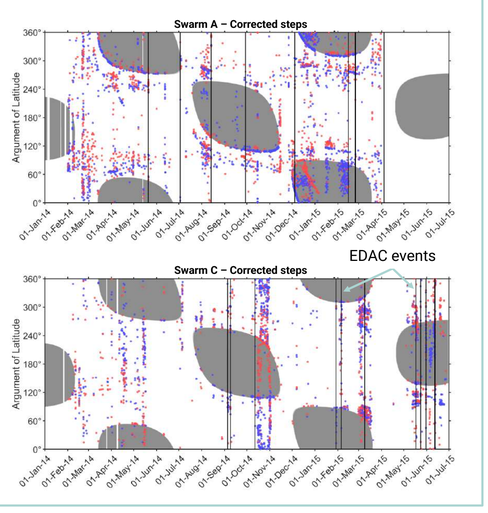
Level 2 calibrated accelerations (ACCxCAL_2) are effectively cleaned up from various anomalies, though a certain Level 1B (ACCx_PR_1B) data quality degradation is visible over the whole mission lifetime.

Most impacting and hard-to-remove data anomalies (corrected in processing)

Steps

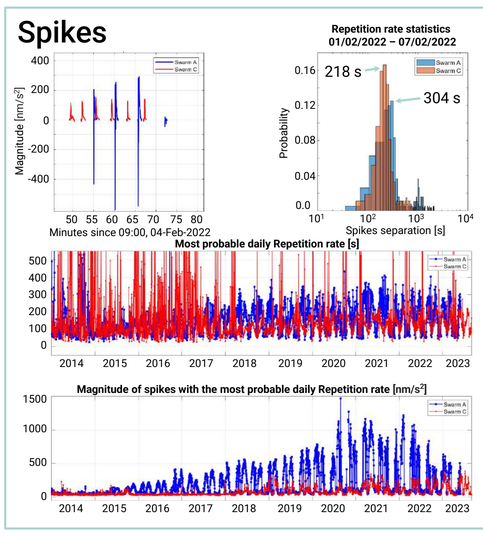


Top: L1B accelerations (blue) are broken as rectangular pulses; automatically estimated steps are shown in red. Bottom: step statistics reveals distinctive peaks with comparable magnitudes.

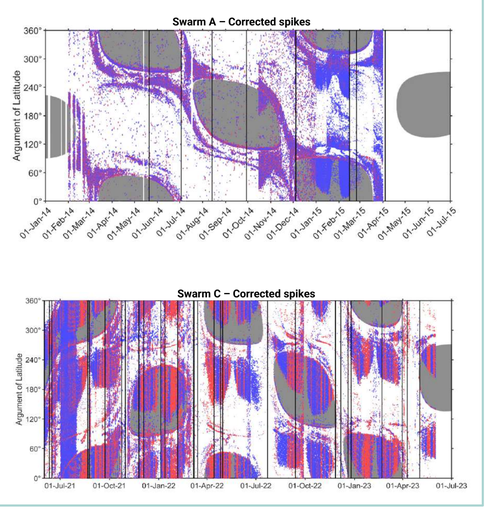


Spatial location of steps on the time and argument of latitude (AOL) plot is different for Swarm A (top) and Swarm C (bottom).

Spikes

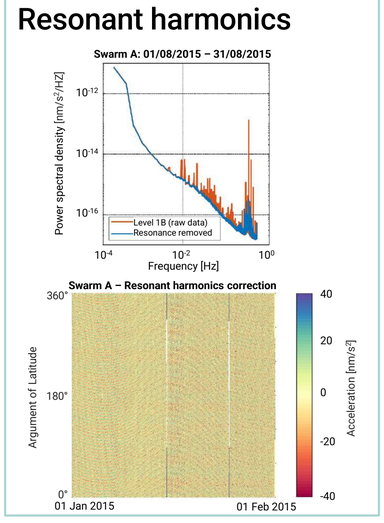


Spikes in Swarm A and Swarm C differ in polarity, magnitude and repetition rate. After peaking in 2021-2022, Swarm A spike's amplitudes go down.



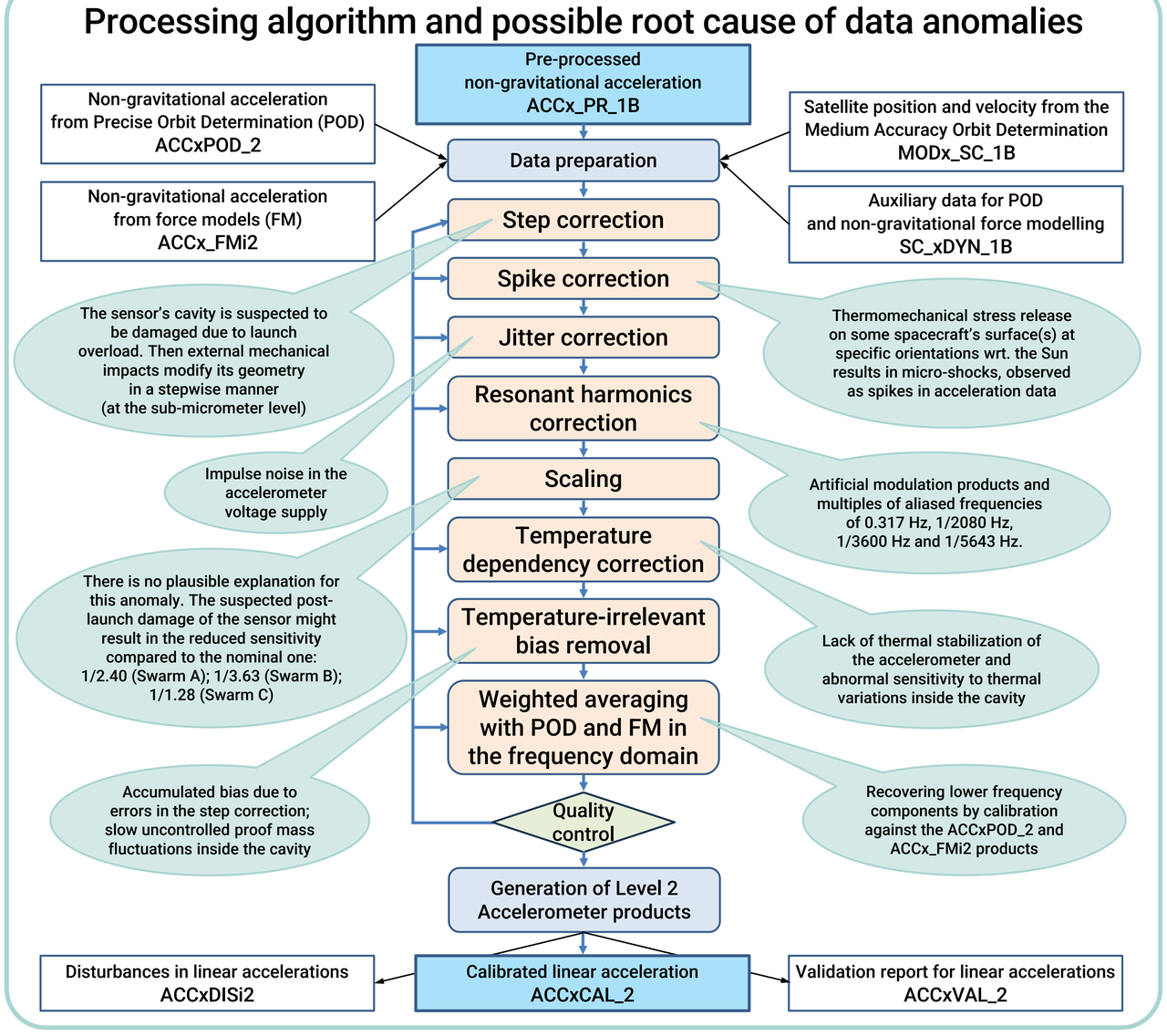
Spatial location of spikes on the AOL plot creates similar, but not identical patterns for Swarm A (top) and Swarm C (bottom) (different epochs are selected).

Resonant harmonics

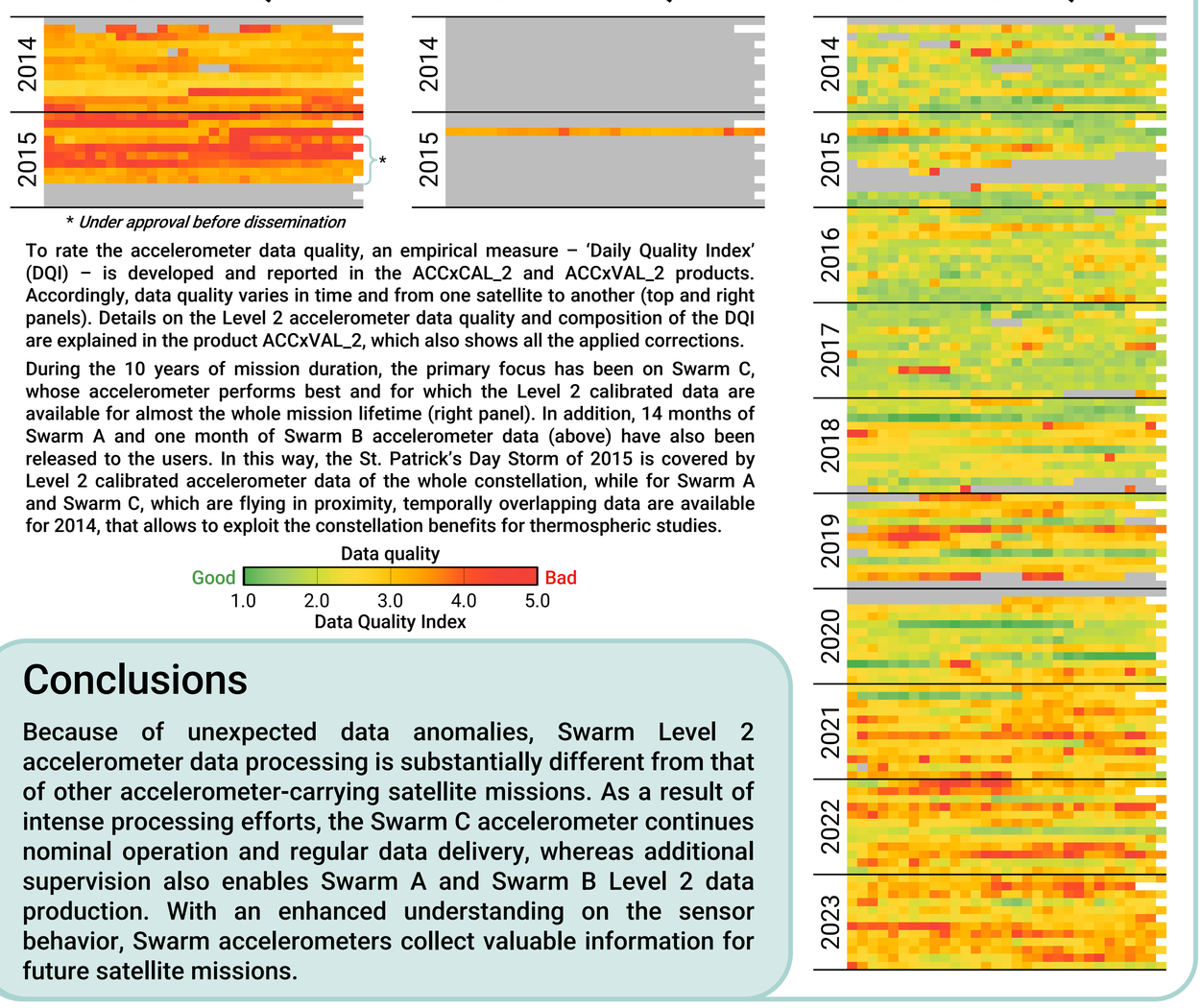


Resonant harmonics add strong high-frequency components to the spectrum (top) and a *moire* pattern to the AOL plot.

Processing algorithm and possible root cause of data anomalies



Level 2 Accelerometer data quality and availability



* *Under approval before dissemination*

To rate the accelerometer data quality, an empirical measure – 'Daily Quality Index' (DQI) – is developed and reported in the ACCxCAL_2 and ACCxVAL_2 products. Accordingly, data quality varies in time and from one satellite to another (top and right panels). Details on the Level 2 accelerometer data quality and composition of the DQI are explained in the product ACCxVAL_2, which also shows all the applied corrections.

During the 10 years of mission duration, the primary focus has been on Swarm C, whose accelerometer performs best and for which the Level 2 calibrated data are available for almost the whole mission lifetime (right panel). In addition, 14 months of Swarm A and one month of Swarm B accelerometer data (above) have also been released to the users. In this way, the St. Patrick's Day Storm of 2015 is covered by Level 2 calibrated accelerometer data of the whole constellation, while for Swarm A and Swarm C, which are flying in proximity, temporally overlapping data are available for 2014, that allows to exploit the constellation benefits for thermospheric studies.

Conclusions

Because of unexpected data anomalies, Swarm Level 2 accelerometer data processing is substantially different from that of other accelerometer-carrying satellite missions. As a result of intense processing efforts, the Swarm C accelerometer continues nominal operation and regular data delivery, whereas additional supervision also enables Swarm A and Swarm B Level 2 data production. With an enhanced understanding on the sensor behavior, Swarm accelerometers collect valuable information for future satellite missions.

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