

First results from SWARM's Absolute Scalar Magnetometers burst mode

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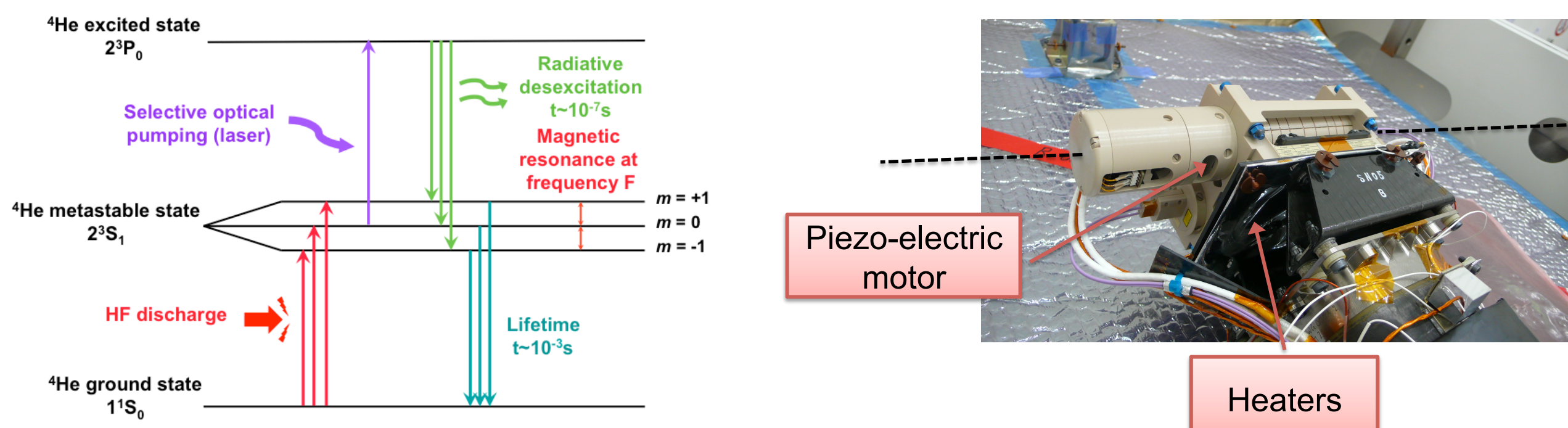
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Summary

Swarm's Absolute Scalar Magnetometers (ASM) provide absolute scalar measurements of the magnetic field with high accuracy and stability on the three satellites of the mission. These ASMs nominally run at 1 Hz. But they can also run at 250 Hz frequency using a so-called "burst" mode. This possibility has been taken advantage of during commissioning, the burst mode having been run simultaneously on all three satellites over several days. These burst mode sessions were driven by the engineering need to explore the high frequency spectral content of the signal measured by the ASMs, to identify issues that could affect not only the nominal 1 Hz scalar data but also the 1 Hz vector data that the ASM simultaneously deliver on an experimental basis (see Poster EGU2014-8749). In the near future, these burst mode data will also be used to look for meaningful high frequency geomagnetic signals.

Two unexpected issues have been identified, one related to the activation of a **piezo-electric motor** built in the instrument (panel 2), the other related to the **heaters** used to keep the instruments within operating temperature range (panel 3). Fortunately, none of the issues affect the nominal 1 Hz scalar data of the mission.

1 ASM instrument and setting



- The core of the ASM instrument is a **magnetic field to frequency** converter based on atomic spectroscopy of the ⁴He in its metastable level 2³S₁. It exploits the Zeeman effect, with the signal being amplified by optical pumping. The magnetic field modulus B₀ is directly proportional to the magnetometer's resonance frequency F :

$$B_0 = F / \gamma^4 \text{He}, \quad \text{with } \gamma^4 \text{He} / 2\pi \approx 28 \text{ GHz/T}$$

- The sensor, including the ⁴He cell, is based on an isotropic design with a static and a rotating part, optimal resonance conditions are controlled by a piezo-electric motor, which is irregularly activated (but on average 500 times per orbit).

- The instrument has a [0-100 Hz] bandwidth and can be run at a **250 Hz Burst mode** (the one investigated in this poster).

- The instrument is located at the tip of the boom, fixed on a bracket with heaters that maintain it within an appropriate temperature range.

Data analyzed

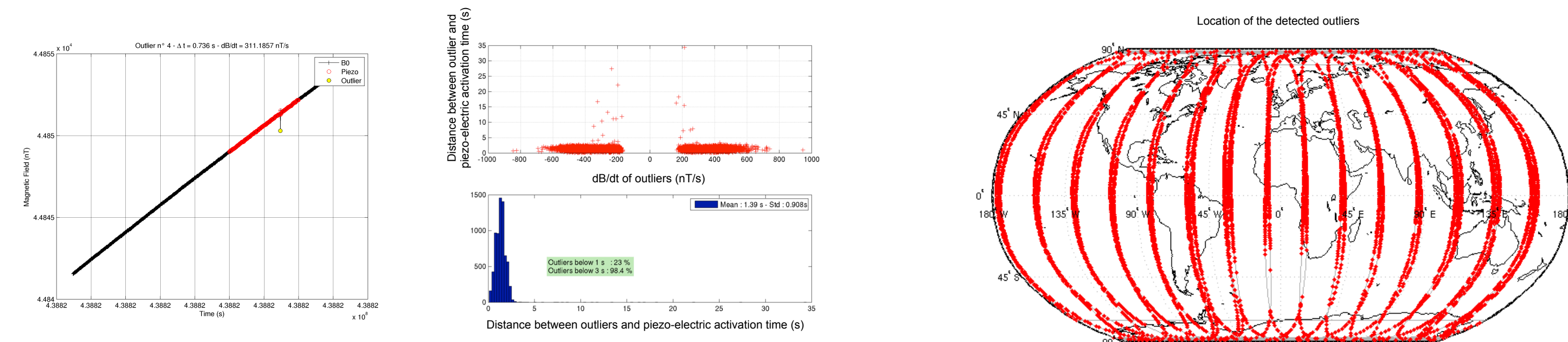
BURST	SAT-A		SAT-B		SAT-C	
	Start	Stop	Start	Stop	Start	Stop
1	26-11-2013 22h35	27-11-2013 03h04	27-11-2013 15h04	27-11-2013 19h31	27-11-2013 06h33	27-11-2013 10h02
2	10-12-2013 21h50	11-12-2013 02h20	11-12-2013 15h10	11-12-2013 19h40	-	-
3	07-01-2014 11h31	08-01-2014 15h00	07-01-2014 13h45	08-01-2014 15h00	07-01-2014 13h45	08-01-2014 15h00
4	19-01-2014 00h00	19-01-2014 23h59	19-01-2014 00h00	19-01-2014 23h59	19-01-2014 00h00	19-01-2014 23h59
5	-	-	28-01-2014 00h00	28-01-2014 23h59	28-01-2014 00h00	28-01-2014 23h59
6	08-02-2014 00h00	10-02-2014 00h00	08-02-2014 00h00	10-02-2014 00h00	08-02-2014 00h00	10-02-2014 00h00
7	22-02-2014 00h00	24-02-2014 00h00	22-02-2014 00h00	24-02-2014 00h00	22-02-2014 00h00	24-02-2014 00h00

Results presented here are based on BURST #3

2 Impact of the piezo-electric motor activation

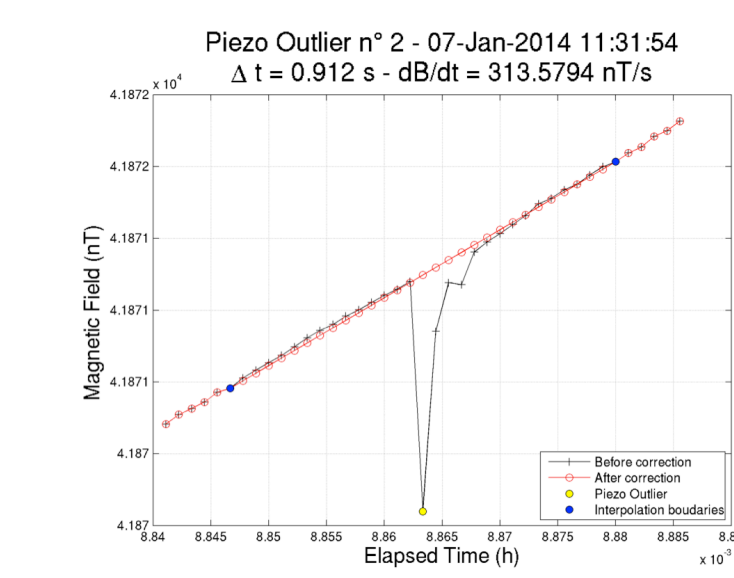
Identification of the issue

- An outlier (large value of dB/dt) may occur in BURST data each time the ASM piezo-electric motor is activated.
- Most of them (**98.4 %**) occur at most **3 s** after the motor activation



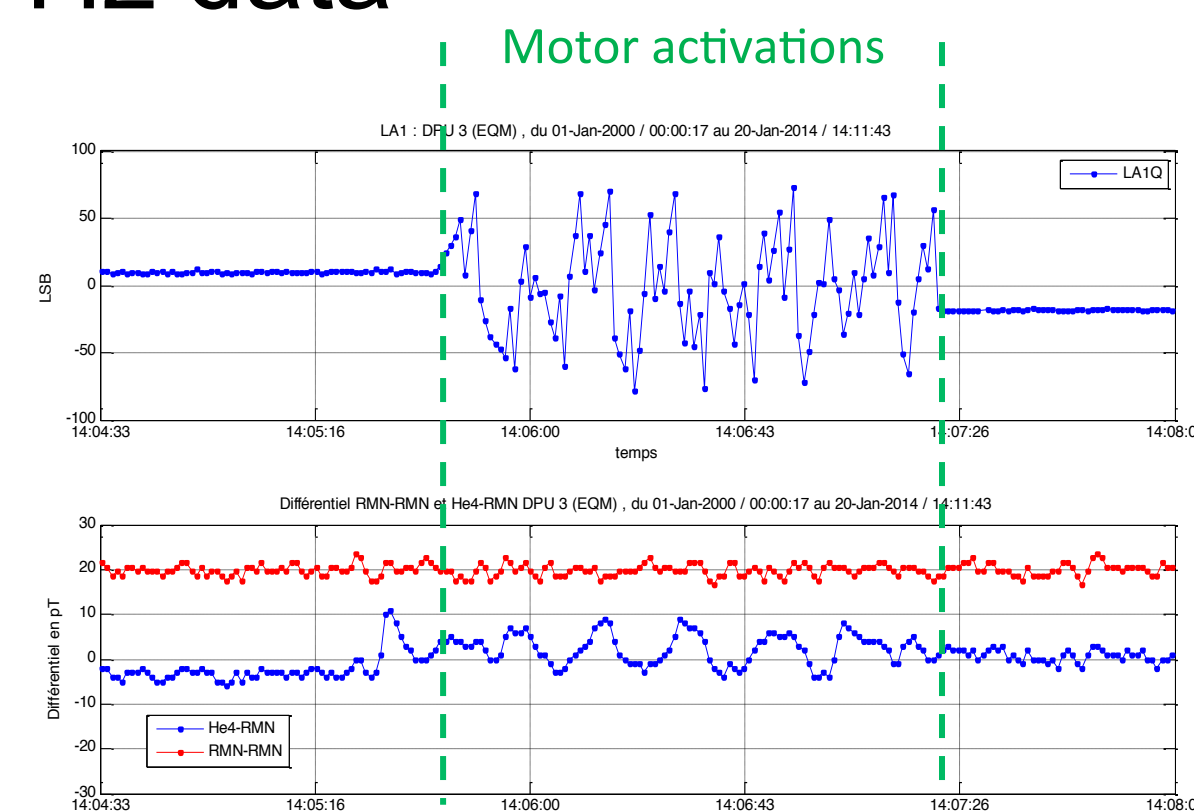
Correction in the Burst mode

- The Burst data can easily be cleaned of the piezo-electric motor effect using a linear interpolation

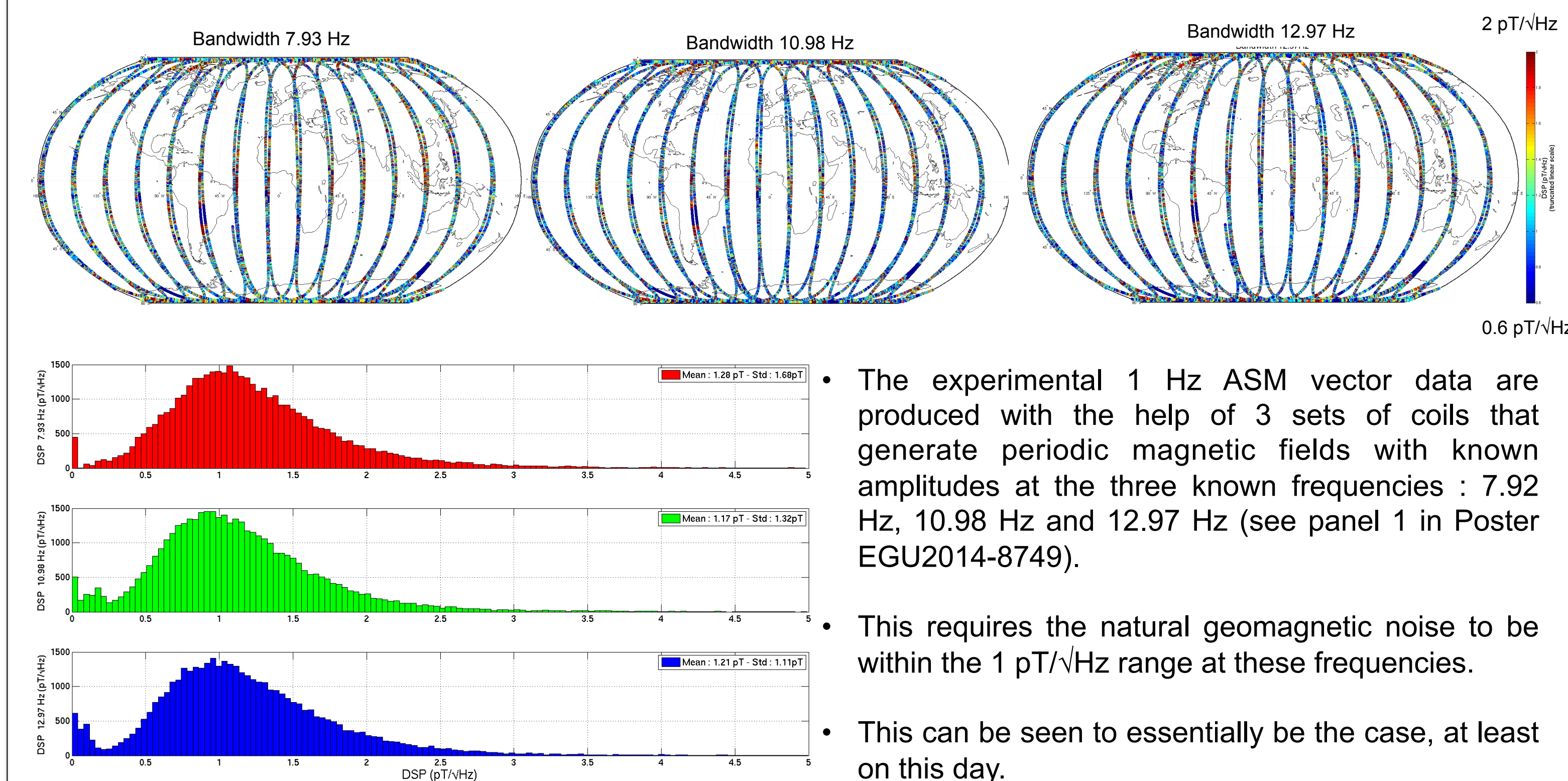


Impact on the nominal 1 Hz data

- When running in nominal 1 Hz mode, the piezo-electric motor may also be expected to perturb the data.
- However, a differential test done with two RMN magnetometers and the EQM ASM model still available on ground has shown the impact to be **less than 10 pT** on the nominal scalar data.
- In contrast, unfortunately, a significant impact is found in the experimental 1 Hz vector data that the ASM simultaneously delivers (on an experimental basis, see panel 5 in Poster EGU2014-8749)



4 Checking the remaining noise level at the frequencies used to produce the experimental 1 Hz ASM vector data



- The experimental 1 Hz ASM vector data are produced with the help of 3 sets of coils that generate periodic magnetic fields with known amplitudes at the three known frequencies : 7.92 Hz, 10.98 Hz and 12.97 Hz (see panel 1 in Poster EGU2014-8749).

- This requires the natural geomagnetic noise to be within the 1 pT/√Hz range at these frequencies.

- This can be seen to essentially be the case, at least on this day.

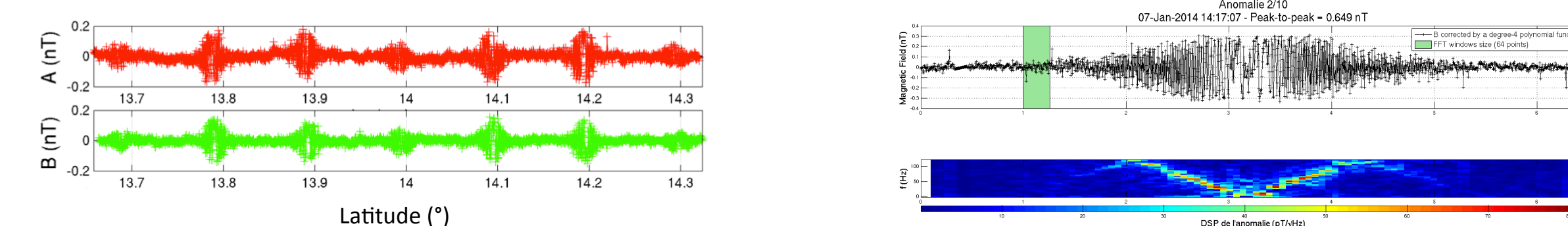
3 Impact of heaters activation

Identification of the issue

- The ASM heaters are powered by a 58 kHz square signal that may interfere with the radiofrequency used to detect the resonance frequency F (recall panel 1). This can be expected to happen every time the magnetic field to be measured is close to:

$$B = B_0 * (1 + 2k) \quad k \in \mathbb{N}, B_0 = 2069,5 \text{ nT}$$

- Indeed, characteristic anomalies signals are detected:

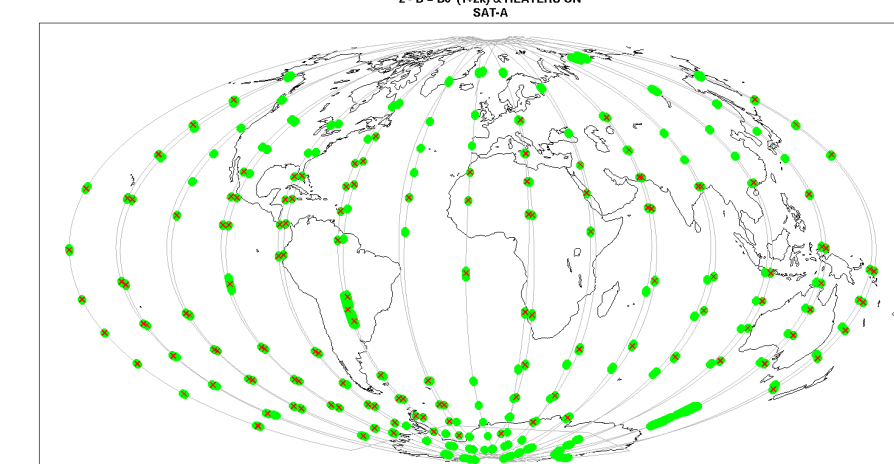


The perturbations caused by the heaters consist in a train of several anomalies

Each anomaly contains two frequency ramps

- These signals occur only when interferences are expected (note however that interferences do not always lead to a detectable signal).

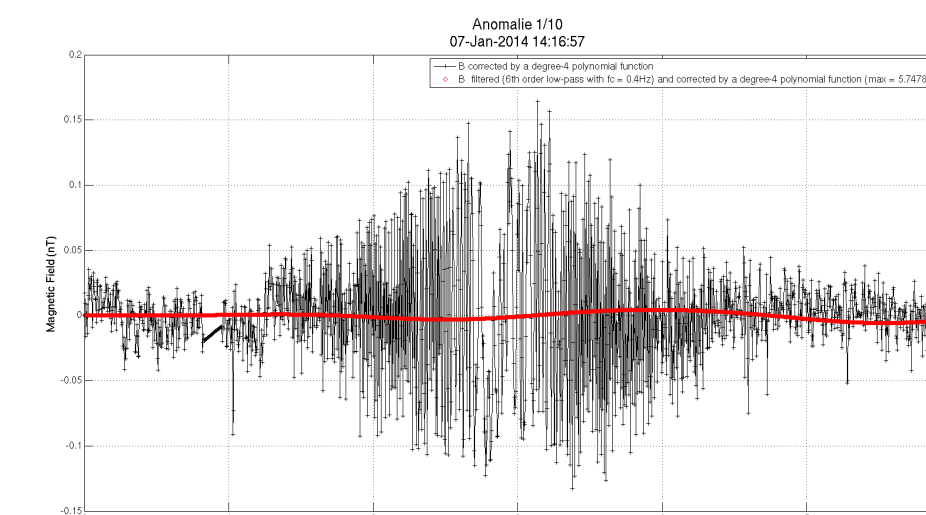
x Perturbation detected
● Heaters condition fulfilled



- Theses anomaly trains can last significant amount of time (most often a few seconds but sometimes 3 minutes).
- For the time being, we simply replaced them by a linear interpolation (replacing the signal by "silence").

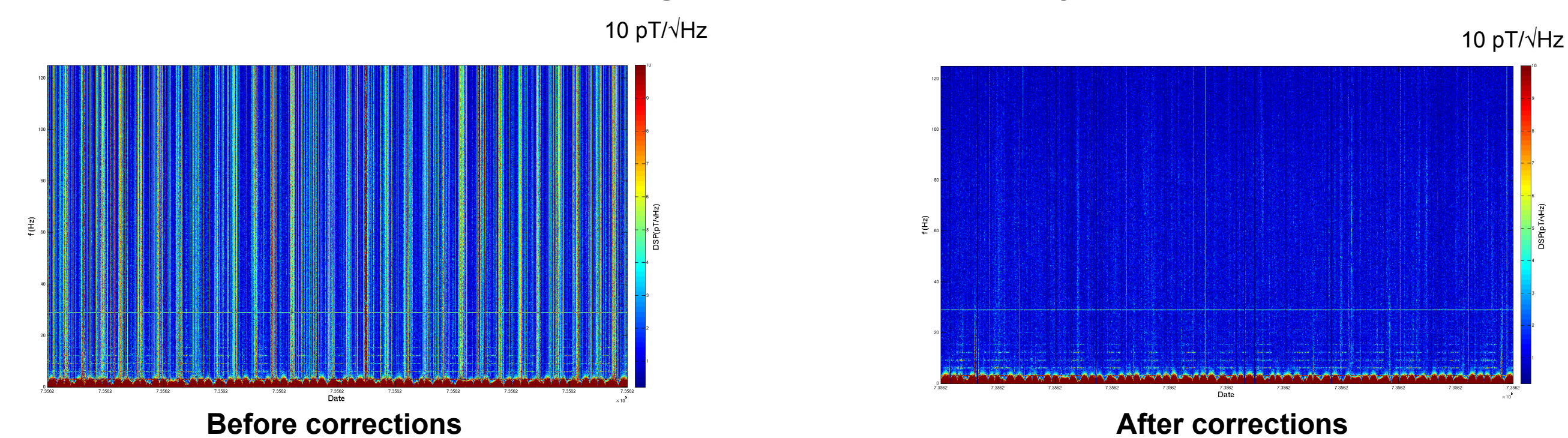
Impact on the nominal 1 Hz data

- When running in nominal 1 Hz mode, these interferences may also be expected to possibly perturb the data.
- However, implementing the filter of the 1 Hz mode to the Burst mode data shows the impact to be within the range of **a few 10 pT at most**.
- Note that such interferences also have little impact on the experimental 1 Hz vector data.



5 Conclusion & Prospects

Running Power Spectral Density



- Analyzing the Burst mode data revealed perturbations produced by the piezo-electric motor and the heaters.
- None of these perturbations affect the nominal 1 Hz scalar data.
- Only the piezo-electric motor produces a significant perturbation in the experimental 1 Hz vector data (see Poster EGU2014-8749).
- The background geomagnetic noise level is compatible with experimental 1 Hz ASM vector measurements.
- Corrected Burst mode data can now be used to look for meaningful high frequency geomagnetic signals.