Comparing Swarm's nominal Level1b magnetic data and ASM vector field experimental data: a convenient tool for understanding data quality issue

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Summary

Swarm's Absolute Magnetometers (ASM) provide scalar measurements of the geomagnetic field with high accuracy and stability on the ALPHA, BRAVO and CHARLIE satellites of the mission.

These measurements are used to produce the (nominal 1 Hz) Level1B scalar data and calibrate the (nominal 1 Hz) Level1B vector data provided by the Vector Field Magnetometer (VFM, located some distance away along the boom on which both instruments are installed).

The very same ASM instruments, however, can also provide independent vector field measurements, which can next be used for comparison with the nominal Level1B vector data for quality crosschecks, possible detection of undesired satellite signals, and assessment of the stability of the mechanical link between both instruments on each satellite.

Here, we report on the lessons learnt from such comparisons, focusing on the issues raised by systematic time-varying differences observed in the nominal L1B data between the modulus of the vector data and the scalar data, testifying for some local perturbations of the field measured.

Note that all plots shown here are for the SWARM satellite ALPHA.

1 SWARM Magnetometers

Each of the three Swarm Satellites carries two magnetometers:

1. The **ASM** is an absolute scalar magnetometer that provides absolute recordings of the Field (nominal L1B scalar data), but can also provide experimental ASMV vector data (**Poster: GP51A-3698**, ref.[1])

2. The **VFM** is a flux-gate magnetometer that provides vector readings of the Field but needs to be calibrated using the ASM scalar data, to provide calibrated vector Field data (nominal L1B vector data)

In what follows, we focus on comparisons between 1 Hz nominal L1B Vector data, nominal L1B scalar data and experimental ASMV data.

2 The scalar residual issue

Initial production of 1 Hz nominal L1B vector data ($\mathbf{B}_{1B}$) revealed that despite the calibration process, the so-called scalar residuals :

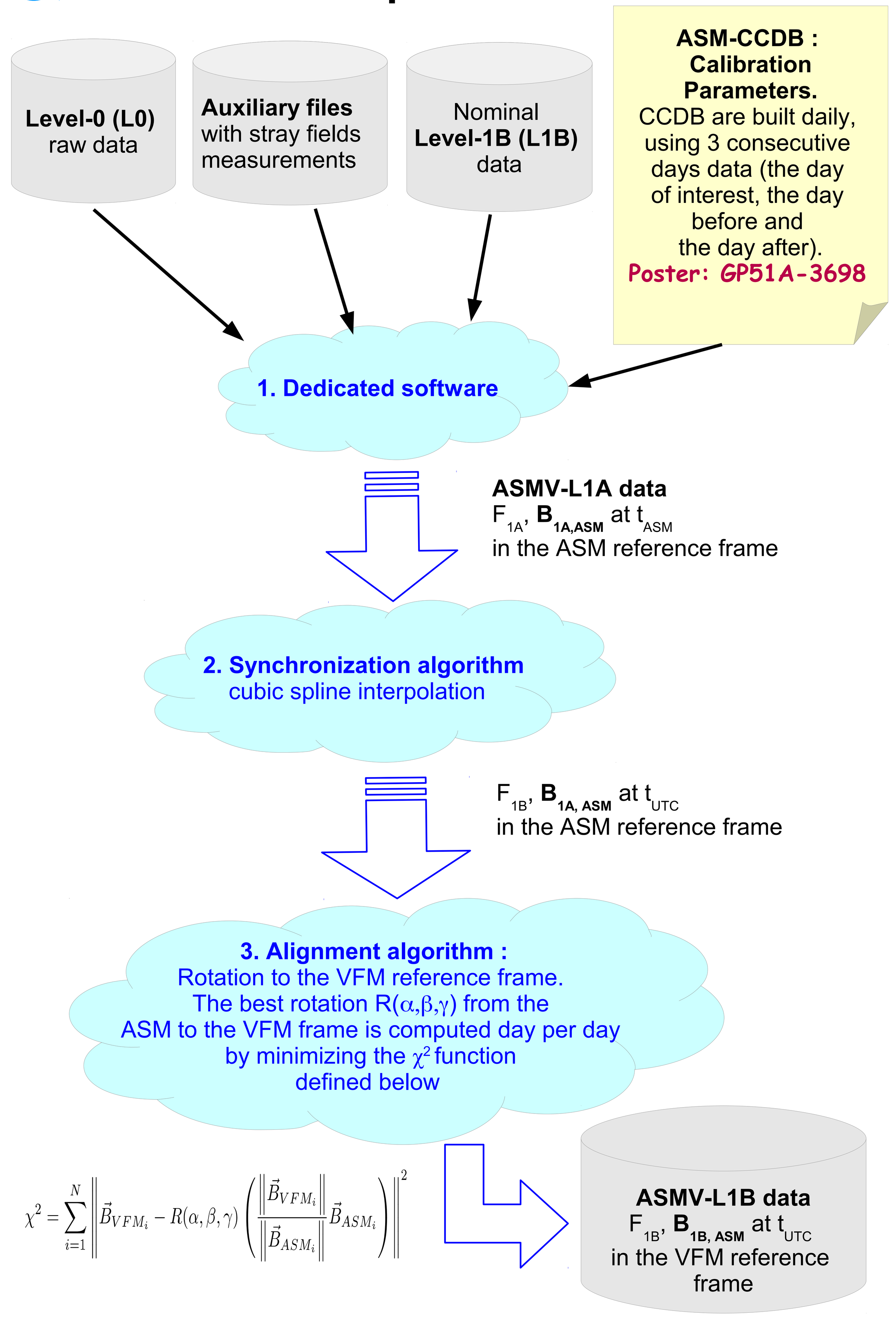
$$R_{1B} = \|\mathbf{B}_{1B}\| - F_{1B}$$

(where F_{1B} is the 1 Hz nominal L1B scalar measurement) could display significant non-zero variations, suggesting the possible presence of a perturbation source close to the VFM instrument.

To investigate the issue, a dedicated L1B dataset was released, calibrated using a single set of calibration parameters (common to all data).

This is the L1B dataset we use here for both scalar residuals investigation and comparison with the 1 Hz experimental ASMV data.

3 ASMV data production



$$\chi^2 = \sum_{i=1}^{N} \left\| \vec{B}_{VFM_i} - R(\alpha,\beta,\gamma) \left(\frac{\|\vec{B}_{VFM_i}\|}{\|\vec{B}_{ASM_i}\|} \vec{B}_{ASM_i} \right) \right\|^2$$

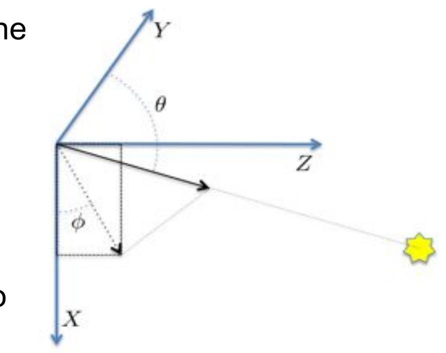
Conclusions and Perspectives

- 1 Hz experimental ASMV vector data can be used for comparison with 1 Hz nominal vector data
- Such comparisons bring useful information for L1B data quality assessment
- In particular, they make it possible to confirm the relevance of the Sun dependent perturbation model of Lesur *et al.* [2].
- Additional systematic differences seen between the experimental ASMV vector data and the nominal L1B vector data are currently under investigation, and are expected to bring additional information about the ASM and VFM instruments as well as the boom linking them.

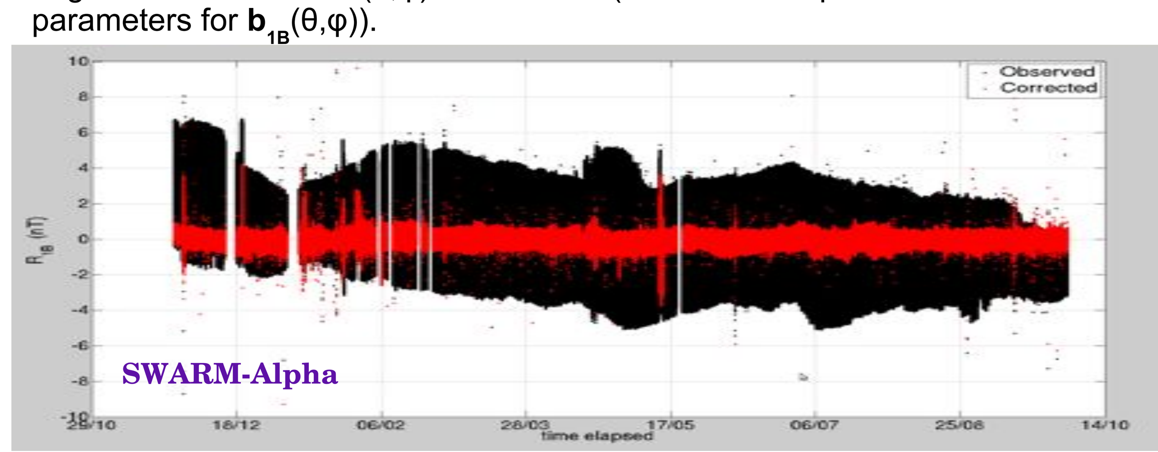
4 The Sun dependent perturbation model (ref. [2])

Scalar residuals R_{1B} appear to be correlated with the relative position of the Sun with respect to the satellite.

This suggests that the magnetic perturbation responsible for R_{1B} could be a function of the solar angles θ and φ defined with respect to the VFM frame of reference (see the figure on the right).



Such a perturbation can then be modelled through a recalibration of the dedicated L1B dataset, using standard calibration parameters and including a solar dependent vector $\mathbf{b}_{1B}(\theta,\varphi)$ offset up to degree and order 30 in (θ,φ) coordinates (13 calibration parameters and ~ 3000 solar-dependent parameters for $\mathbf{b}_{1B}(\theta,\varphi)$).



This recalibration is a success on two accounts :

1. $\mathbf{b}_{1B}(\theta,\varphi)$ takes significant values only when the Sun is in view

2. The new scalar residual is considerably reduced and stabilized. This can be seen in the figure on the left, showing the solar residuals initially observed (in black) and after recalibration (in red).

5 Validation of the Sun perturbation model using experimental ASMV data

Comparison are being done with respect to the original dedicated L1B dataset ($\mathbf{B}_{1B}$) as well as with respect to the corrected (recalibrated, see box 4) L1B dataset ($\mathbf{B}_{1BCorr}$). In each case the ASMV data are first aligned with respect to the VFM reference frame, using the corresponding L1B dataset (Step 3 in box 3).

VFM-ASMV vector residuals can then be computed in the VFM reference frame (with respect to the original and corrected L1B datasets respectively):

$$R_{1B,j} = B_{ASM1B,j} - B_{1B,j} \quad \text{and} \quad R_{1BCorr,j} = B_{ASM1B,j} - B_{1BCorr,j} \quad \text{where} \quad j=x,y,z$$

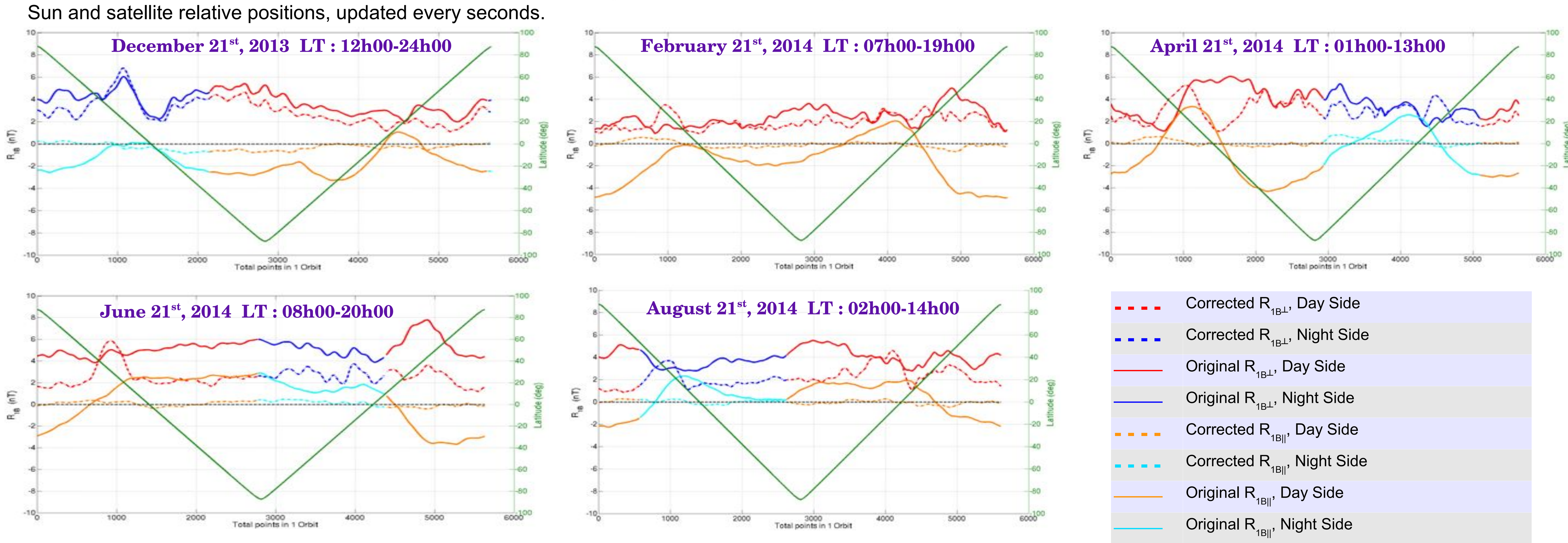
Of greatest interest are the Field-aligned ($R_{\parallel}$) and Field-perpendicular ($R_{\perp}$) components of these vector residuals:

- By design of the perturbation model, $R_{1BCorr,\parallel}$ must be much reduced compared to $R_{1BCorr,\perp}$
- In contrast reduction of $R_{1BCorr,\perp}$ compared to $R_{1B,\perp}$ is a test.

Below we plot $R_{1B\parallel}$ and $R_{1B\perp}$ before (continuous line) and after (dotted line) applying the Sun perturbation model, for satellite **ALPHA** and for 5 representative days, between December 2013 and August 2014. In all figures:

→ The average curves (over 14 complete orbits) of the low-pass filtered (5 mHz) residuals are plotted as a function of the the time elapsed since descending from the North Pole. Also shown in green is the geographical latitude.

→ We distinguish between day (fully lighted, red & orange) and night (dark, blue & cyan) segments of the orbit. Sun illumination of the satellite has been estimated from the Sun and satellite relative positions, updated every seconds.



- As can be seen, not only $R_{1B\parallel}$ (as expected) but also $R_{1B\perp}$ are reduced by the correction. In the latter case, the variance reduction (over all orbits) decreases from $\sigma_{\perp} = 4.4$ nT to $\sigma_{\perp} = 3.1$ nT.
- Note, however, that systematic disagreements are still detected, particularly at ± 20/30 Latitudes.

References

[1] GP515A-3698: In Flight calibration of the experimental Absolute Scalar Magnetometer vector mode on board the Swarm Satellites, Jager, T. *et al.*

[2] Lesur, V., Rother, M. and Michaelis, I. (2014), Swarm-A ASM/VFM differences, the Sun dependence hypothesis. Swarm data quality workshop, 2-5 December 2014, GFZ, Potsdam, Germany

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