# Swarm's Absolute Scalar Magnetometers experimental vector field measurements: first conclusions from comparisons with preliminary nominal Swarm Level1b vector data


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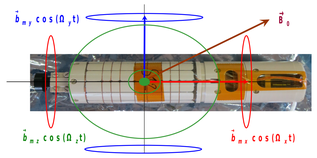
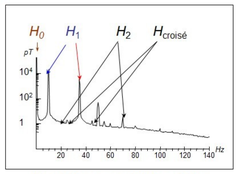
## Summary

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. In addition, and on an experimental basis, these ASM instruments can simultaneously provide vector field measurements. These measurements can be compared with readings from the Vector Field Magnetometer (VFM, located some distance away along the boom and used to produce the nominal Swarm Level1b vector data) for quality cross checks, possible detection of undesired satellite signals, as well as assessment of the stability of the mechanical link between both instruments. Here, we explain how such cross checks and comparisons, which imply using appropriate synchronization and alignment procedures, are being made and provide very encouraging first results.


## 1 Principle of the ASM vector measurement






Real time analysis of the scalar output

$$\| \mathbf{B}_{tot} \| = \| \mathbf{B}_0 + \sum_{i=x,y,z} \mathbf{b}_{mi} \cos(\Omega_i t) \|$$

- Three perpendicular coils generate periodic magnetic fields with known amplitudes (~ 50 nT) and three different known (and adjustable) frequencies beyond 1 Hz (7.92 Hz, 10.98 Hz and 12.97 Hz) .
- Real time analysis (with 250 Hz sampling rate) of the scalar field measured by the (scalar) sensor makes it possible to measure the scalar field at 1 Hz (with nominal performance) together with all field components along the three coil axis.
- Some calibration is needed to scale the response to the three sets of coils and take into account the non-orthogonality of the three axes, the thermal impact and the position of the rotating sensor within the instrument (CCDB parameters).

## 2 L1A data production

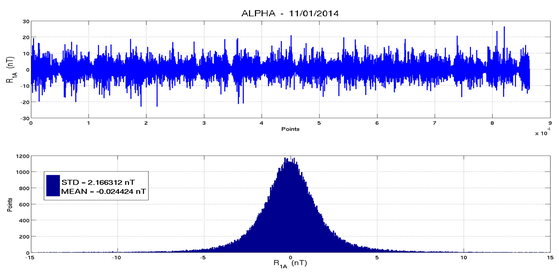
- The ASMV-L1A data are generated via a dedicated software. The inputs required by the software to produce 1 day of data are:
  - The Level-0 (L0) raw data
  - The auxiliary files with the stray fields measurements
  - The calibration parameters (CCDB). For each day a different CCDB is used. Each CCDB is built using three consecutive days data (the day of interest, the day before and the day after).
  - The nominal Swarm Level-1B (L1B) data (for auxiliary information

This chain produces both scalar ($F_{1A}$) and vector field ($\mathbf{B}_{1A}$) values in the ASM (coils) reference frame at instrument times $t_{ASM}$ with 1 Hz sampling rate.

- The L1A data are then synchronized at UTC time using a cubic spline interpolation. The estimated error on the interpolation is ~ 0.01 nT.

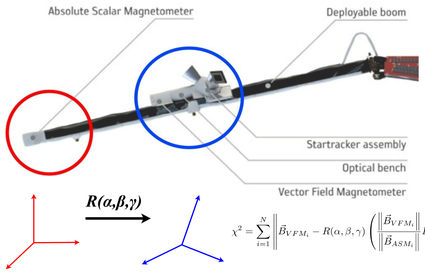
In this Poster are presented the results obtained using the L0 files *v.2.0* and L1B files *v.1.0*. One day (**January 11, 2014**) residuals for the synchronized ASMV-L1A data of satellite **Alpha** are displayed below.

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




## 3 Alignment of the ASM vector measurements

- Using synchronized ASMV-L1A and nominal L1B (VFM) 1 Hz vector data
- We seek the best rotation R(α,β,γ) from the ASMV to the VFM instrument frames minimizing $\chi^2$ (see below).

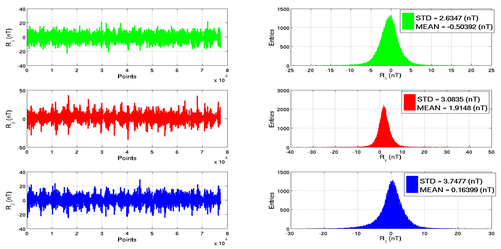



$$\chi^2 = \sum_{i=1}^{N} \left\| \vec{B}_{VFM_i} - R(\alpha,\beta,\gamma) \left( \frac{\left\| \vec{B}_{VFM_i} \right\|}{\left\| \vec{B}_{ASM_i} \right\|} \vec{B}_{ASM_i} \right) \right\|^2$$

- Residuals between the rotated ASMV and the VFM data for the three magnetic components ($B_x$, $B_y$, $B_z$) in the VFM frame are plotted below for satellite **Alpha**, on **January 11, 2014.**

$$R_j = B_{j,ASM\text{-}V} - B_{j,1B} \qquad j=x,y,z$$

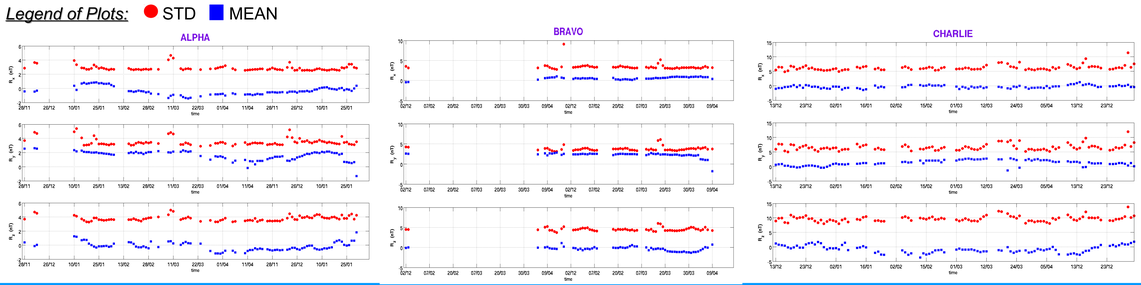
- Note the overall consistency of these residuals with those shown for the ASMV-L1A data in panel 2




- Figures below illustrate the evolution over four months of the mean and std of the residuals for the three components and the three satellites.

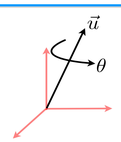
As can be seen, the quality of the alignment is very stable (but not yet quite as good for Charlie, as for Alpha and Bravo).

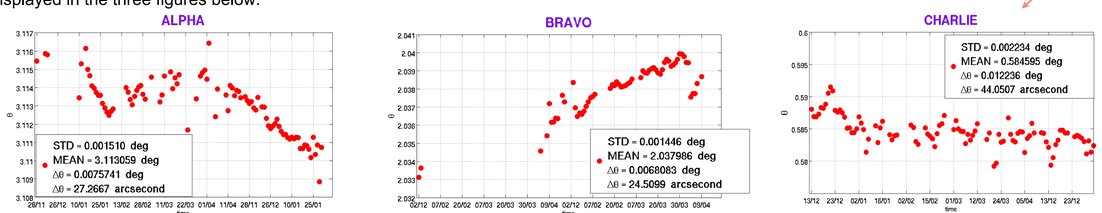
*Legend of Plots:* ● STD ■ MEAN




## 4 ASMV – VFM alignment stability

- The recovered rigid rotation between the ASMV and VFM reference frames can be characterized by an angle θ and a unit vector **u**.
- Both quantities are evaluated on a day by day basis.
- For all satellites **u** is quasi-coincident with the z-axis of the VFM frame and constant over the four months; the behaviour of θ is displayed in the three figures below.

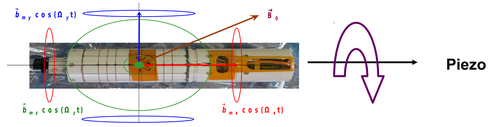


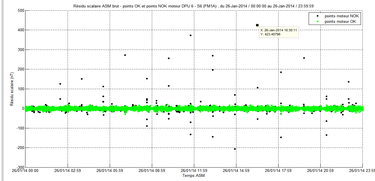




- Note the good overall stability, consistent with the residuals shown in panel 3
- Note also the greater uncertainty on Charlie (consistent with the greater residuals in panel 3 ).
- Note, finally, the possible existence of a slow long-term drift.

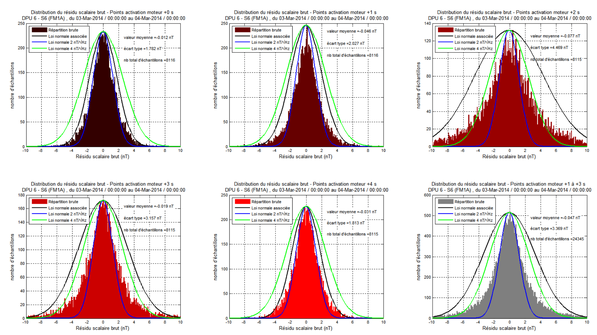
## 5 A comment on ASMV outliers

- The main cause of occurrence of outliers has been identified as being the activation of the piezoelectric motor (needed for maintaining some orthogonality conditions with respect to $\mathbf{B}_0$ in the sensor).



- As displayed in the figure on the left, largest outliers in the ASMV-L1A residuals (black points) are generated within 3 seconds after the activation of the piezoelectric motor.
- As illustrated in the panels below, avoiding the data collected within 2 to 3 seconds after the activation of the piezoelectric motor significantly improves data quality.



- This shows that proper data selection should help in removing outliers and further improve the ASMV data quality.

## 6 Conclusions and Perspectives

- After commissioning and improvements in calibration procedures, the vector components of the ASM experimental vector mode in the ASM frame of reference are now close to their expected data quality (except for satellite Charlie).
- Alignment of these ASMV vector data with the nominal L1B (VFM) data reveals a very good mechanical stability between the two ASM and VFM instrument frames.
- As a result, a good mechanical stability is also to be expected between the ASM and the star tracker assembly (STR),
- ASMV components in the North East Center (NEC) reference frame could thus be derived jointly with a field model (to produce ASMV L1B NEC data independent from the nominal L1B NEC data).
- There is also still room for further improvement in the ASMV data quality.