Recent updates on Swarm L1B and L2 operational processors
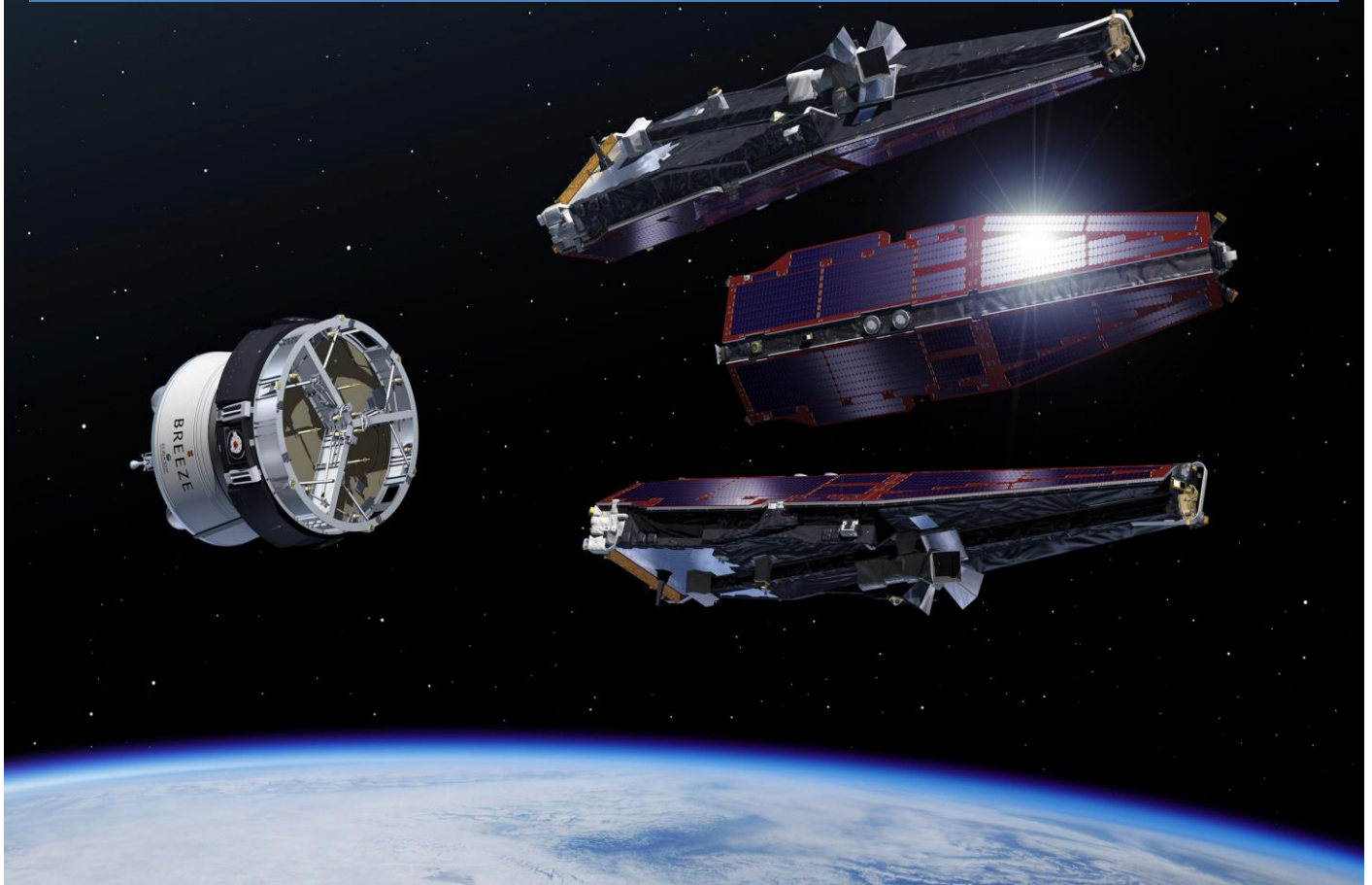
Prepared by	**Enkelejda Qamili on behalf of the Swarm Data Quality Team**
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1   INTRODUCTION

1.1   Scope

This document describes the recent modifications introduced in Swarm L1B and L2 data processing chain. Such improved L1B and L2 Cat-2 operational processor has been transferred into operations on 28/09/2022 and immediately a full reprocessing campaign was performed. Please note that such changes have caused a Product Baseline and File Counter increase for all the L1B and L2 Cat-2 products:

L1B/L2 processors	New Product Baseline and File counter
ORBATT	0502
MAGNET	0602
PLASMA	0602
ACCELE	0502
FAC (Singe & combined)	0401
IBI	0401
TEC	0401

1.2   Reference documents

[RD.1]   SW-RS-DSC-SY-0002, Level 1B processor algorithm

[RD.2]   SW-RS-DSC-SY-0007, Level 1b Product Definition

[RD.3]   ESA-EOPG-EOEP-TN-24, Review of Swarm L1B data quality

[RD.4]   Lomidze, L., Knudsen, D. J., Burchill, J., Kouznetsov, A., & Buchert, S. C. (2018). Calibration and validation of Swarm plasma densities and electron temperatures using ground-based radars and satellite radio occultation measurements. Radio Science, 53, 15– 36. https://doi.org/10.1002/2017RS006415

[RD.5]   SW-TR-GFZ-GS-0005, Swarm L2 FAC-single Product Description

[RD.6]   SW-TR-GFZ-GS-008, Swarm L2 FAC-dual Product Description

[RD.7]   SW-TR-GFZ-GS-0006, Swarm L2 IBI Product Description

[RD.8]   SW-TR-GFZ-GS-0007, Swarm L2 TEC Product Description

1.3   Context

This document contains a brief description of the changes introduced in L1B algorithm with respect to previous version [RD.1], together with the updates related to operational system for both the L1B and L2 processors.

It is worth to specify that the L1B processor comprises of four individual processors ([RD.2]):

The ORBATT processor, which generates the following orbit and attitude data products:
- o   GPSx_RO_1B
- o   GPSx_RN_1B
- o   MODx_SC_1B
- o   GPSxNAV_1B
- o   STRxATT_1B

The MAGNET processor, which generates the following magnetometer related data products:
- o   VFMxAUX_1B
- o   ASMxAUX_1B
- o   MAGx_LR_1B
- o   MAGx_HR_1B
- o   MAGx_CA_1B

The PLASMA processor, which generates the following electric field related data products:
- o   EFIx_LP_1B
- o   EFIxLPI_1B
- o   LP_x_CA_1B

The ACCELE processor, which generates the following accelerometer related data products:
- o   ACCx_PR_1B
- o   SC_xDYN_1B

2 MAIN EVOLUTIONS OF THE L1B DATA

In this chapter are described the main evolutions of the L1B data production. A dedicated section for each processor will describe the related data quality improvements.

2.1 ACCELE

The new version of the ACCELE processor introduces two main evolutions, that are:

- **Improve thruster activation information stored SC_xDYN_1B**: In the previous version ofSC_xDYN_1B the information on the thruster activation was often not correct. In the current version this issue has been fixed and now the thruster activation information is stored correctly.

- **New Flags_q parameter stored in SC_xDYN_1B**: The Flags_q parameter is now stored in SC_xDYN_1B product. Such new parameter will provide info on Swarm attitude accuracy.

2.2 ORBATT

The new version of the ORBATT processor introduces two main evolutions, that are:

- **Removed the duplicated timestamp in GPS RINEX files**: In the previous version of ORBATT processor, the GPS RINEX files had sometime duplicated timestamp stored in the output files. In the current version this issue has been fixed.

- **Improved thermal model for Inter Boresight Angle (IBA) variation:** as described in [RD.3], the only known issue present in STR data is an anomalous variation (up to ~0.85 arc-sec/°C) in the IBA for the CHU pairs. A correction thermal model was previously introduced to compensate this effect, allowing to perform both pre-flight and in-flight IBA measurements. With this new L1B version, a new model has been introduced which improves the accuracy in the star attitude measures of ~2%.

2.3 MAGNET

The new version of the MAGNET processor introduces four main evolutions, which are:

- **Improved dB_Sun and new dF_Sun stray fields**: As described in [RD.3], although the operational dB_Sun correction model transferred into operations in the Swarm L1B data production chain in July 2015 is performing very well, the MMEG (Magnetic Measurements Expert Group) has continued to investigate the root-cause of the Sun-induced disturbance. On this respect, a thorough on-ground magnetic survey of the materials around the VFM sensor has been performed. Such ground survey was focused on thermoelectric currents. From the results obtained, it was concluded that the observed perturbation is generated by thermoelectric current running in the MLI blanket of VFM instrument and returning through the grounding network, i.e., this grounding is done at two rivets on the blanket connecting the aluminized MLI blanket and an outer titanium wire with copper wires to the grounding network. Another very interesting finding of such survey was that not only the VFM instrument but also the ASM instrument places at the tip of the Swarm boom is affected by such disturbance. Thanks to a further joint effort of the MMEG, which makes usage of abovementioned findings, an updated Sun induced magnetic disturbance, i.e., dB_Sun, is now applied to VFM data and a new Sun induced magnetic disturbance, i.e., dF_Sun, is applied to ASM data. In conclusion, the new stray field dF_Sun parameter is now stored in the following magnetic products: MAGx_LR_1B and MAGx_CA_1B. While a new dB_Sun parameter is now stored in ASMxAUX_1B.
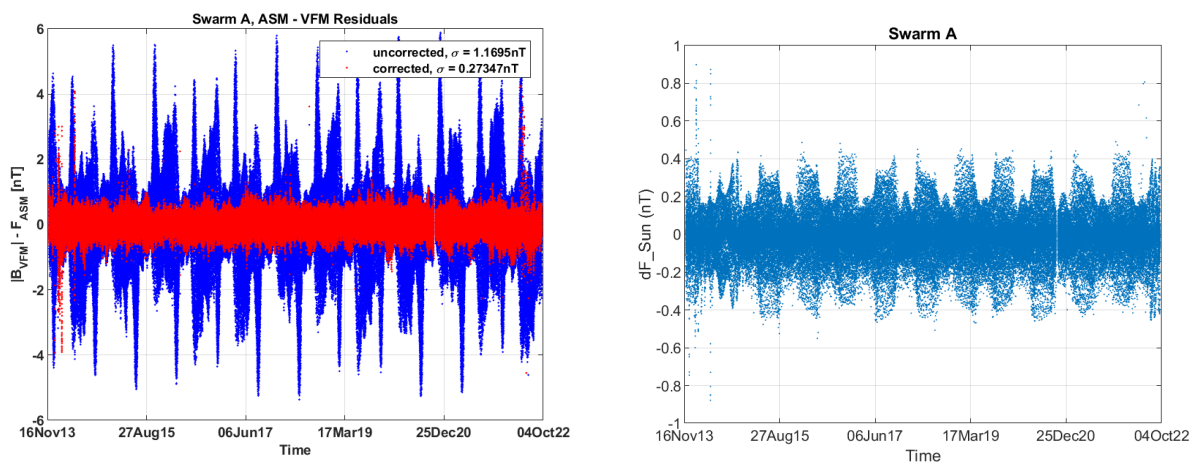

Figure 1: (left) Trend of the ASM -VFM scalar residuals before and after the correction for Swarm Alpha and (right) time series of dF_ASM parameter stored in MAGA_LR_1B products.

- **Improve F_ASM data processing during Burst Mode sessions**: The ASM (Absolute Scalar Magnetometer) instruments, on board Swarm Alpha and Bravo satellites, are more and more often commanded in burst mode, to measure the magnetic field intensity with a cadence of 250 Hz. With the previous version of L1B operational processor, the magnetic field intensity derived from the ASM stored in MAGx_LR_1B and MAGx_CA_1B products was set to zero during ASM Burst mode sessions when the following conditions were registered:

> o mixed ASMxVEC_0_ / ASMxBUR_0_ data (mainly to properly process the first and the last day of Burst Mode sessions).
> o gaps shorter that 15 seconds present in the telemetry files.

With this new version, the MAGNET processor is able to produce the 1Hz magnetic field intensity derived from the ASM and stored in in MAGx_LR_1B and MAGx_CA_1B when the above conditions are registered.

- **Run MAGNET when no VFM data are available**: When VFM Level 0 data are not available, the previous version of MAGNET processor was not able to run and generate the Swarm ASM data as output, since the availability of these L0 data was mandatory for MAGNET processor. With this new version, MAGNET processor is able to process only the available data and generate L1B ASM data.

- **Use of POD as input for MAGNET**: We have adapted the Swarm L1B MAGNET processor to read POD (Precise Orbit Determination) instead of MOD (Medium accurate Orbit Determination) as input. Please note that the POD input file can be used only during a full reprocessing campaign and not during daily nominal L1B data production.

2.4   PLASMA

The new version of the PLASMA processor introduces two main evolutions, that are:

- **LP calibration parameter**: The LPs measurements have been statistically validated by a comparison with Incoherent Scatter Radars (ISRs) located at low- and mid-latitude [RD.3]. The results demonstrate that Swarm LP measurements underestimate the plasma density by approximately 20% and overestimate the electron temperature by approximately 400 K. The new version of the PLASMA processor includes the results of [RD.3] to derive the calibration parameters for Swarm LP density and electron temperature measurements. The calibration parameters represent the correction to LP data to obtain a better agreement with ground measurements. These parameters are stored in the cdf fields named Ne_error and Te_error. The parameters have positive or negative sign representing an upward or downward correction to be applied to LP variables. The calibration parameters are not available for all the samples, but are computed only for certain latitudes reflecting the geographical location of ISRs used for their computation. In Figure 2 is reported an example of the Ne and Te calibration parameters.
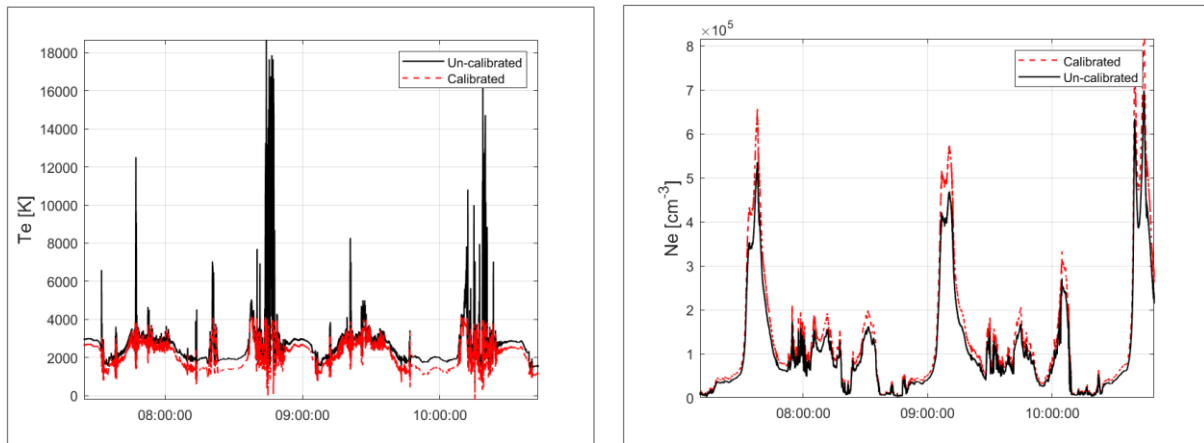
Figure 2: Time series of plasma density (left) and electron temperature (right) measured by Swarm A on 01/02/2020, having magnetic local time spanning from 7 am to11 am. The black lines are the nominal LP data, while red lines are LP data calibrated by adding the LP calibration parameters.

- **Flag's improvements**: The LP Flag table have been updated in order to have a single Flag value related to a single case description. This modification allows to align the LP flags with the flag tables of the others Swarm data products. The new Flag_Xx equal to 19 (Xx stands for Ne, Te, or Vs) has been added to indicate the data samples for which the LP calibration parameters are computed. Also, the Flag_Te equal to 36 is introduced to identify the extreme Te values, namely the measurements larger than 20e4 K. These values are considered to be related to some instrumental disturbance. More investigations are ongoing.

3 MAIN EVOLUTIONS OF THE L2 CAT-2 DATA

Following the evolutions introduced in the Swarm L1B data production chain, for consistency reasons, a full reprocessing of Swarm L2 (FAC (Field Aligned Currents) single [RD.5], FAC dual [RD.6], IBI (Ionospheric Bubble Index) [RD.7] and TEC (Total Electron Content) [RD.8]) has been performed. However, please note that all the L1B data improvements have a negligible impact on L2 IBI, FAC and TEC products.