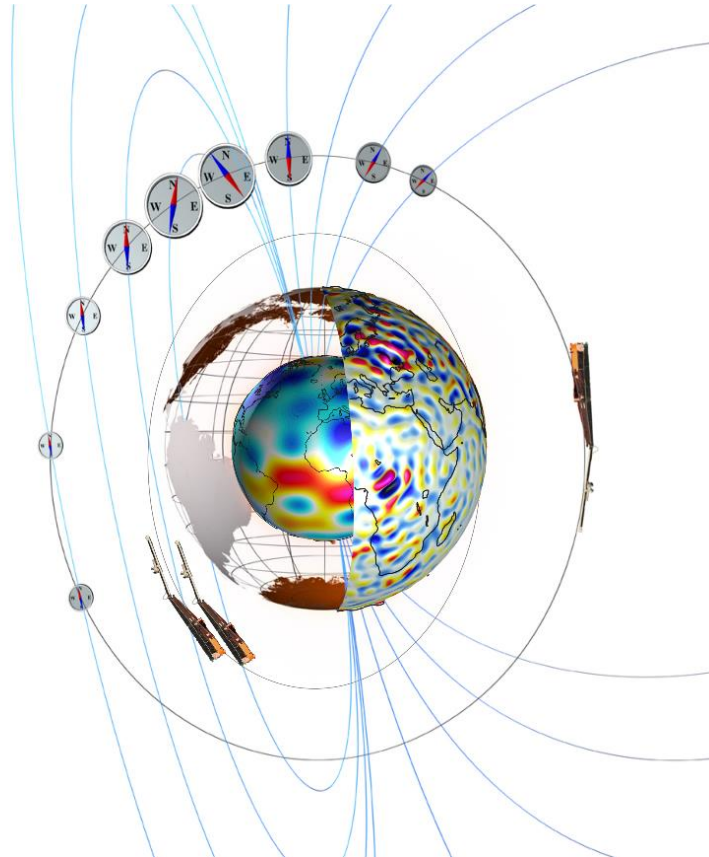


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# Swarm DISC Weekly Report 2017/02: 2017/01/09 - 2017/01/15

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**Abstract** : This is the **Swarm Data Innovation and Science Cluster** (Swarm DISC) Swarm Weekly report on Swarm products quality, covering the period from 09 January to 15 January 2017.

**Doc. No** : SW-RP-SER-GS-010

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## AMENDMENT POLICY

This document shall be amended by releasing a new edition of the document in its entirety. The Amendment Record Sheet below records the history and issue status of this document.

### AMENDMENT RECORD SHEET

ISSUE	DATE	REASON
1.0	06 Feb 2017	First issue

## 1. Introduction

This document refers to the activities carried out in the framework of the Sensor Performance, Products and Algorithms (SPPA) Office [RD.1], and as such, it reports on work related to:

- Algorithms and Processors Development, Maintenance and Evolution: these include all algorithm and software evolution and maintenance aspects for the different components, for both the Operational processors (OP) and Prototypes processors (PP) of L1 and L2 chains.
- Performance Assessment: these include all Quality Control activities (on-line and offline, systematic or on-demand), for the applicable product levels.
- System Calibration: these include the activities related to calibration, from sensor to system level. They also include aspects like cross calibration and handling of external calibration sources.
- Product validation: these include definition and maintenance of product validation plans.
- End-to-end Sensor Dataset Performance: these include activities related to the organisation and coordination of Quality Working Groups and all aspects of the Experimental platform. It also covers the product baseline, coordination and handling of external communities, and all aspects of APDF (Archive and Processing Data Facility) handling (both for the operational processors and for the prototypes).

This weekly report constitutes a work in progress throughout the mission lifetime, and new parts and complements will be added while the consolidation of knowledge on Swarm data and instruments will progress.

Section 2.1 always gives an overview of the general quality status of the mission instruments and products, while the main observations of the week are summarized in Section 2.1.

The document also includes information on data quality for the three Swarm spacecraft, inferred from automated HTML quality reports, which are produced on daily basis for each product. Please contact the Swarm DISC team if interested in accessing the reports via web or FTP (all details about interfaces and folder structure available on [RD.2]). Such quality reports represent the core of the Routine Quality Control (Chapter 3). A description of the implemented quality checks is given in [RD.3], and references therein.

Basing on specific findings of the routine quality control, or on-demand from other entities (i.e. Swarm Payload Data Ground Segment (PDGS), Flight Operation Segment (FOS), Mission Management, Post-Launch Support Office (PLSO), Expert Support Laboratories (ESL), Quality Working Groups (QWG), and user community), anomalies can be triggered. Preliminary characterisations and investigations of such anomalies are given in Chapter 4. The anomalies documented in the Weekly Reports are tracked in the following way:

1. If triggered by ESA Eohelp or within the Service: DISC action and ticketing system (<http://requests-sppa.serco.it/RT3/index.html>, for authorised personnel only).
2. If triggered by Swarm Disc team or other entities:
  - 2a. if the observation/analysis leads to an anomaly to be addressed to the processor provider (GMV): SPR on EO ARTS (<https://arts.eo.esa.int>, for authorised personnel only), SWL1L2DB project;
  - 2b. if the observation/analysis does not lead to an anomaly or the investigation shall be escalated to other entities (PLSO/industry, ESL, and PDGS): Action tracked on EO ARTS, SW-IDEAS project, then addressed to the proper tracking system if needed (e.g. JIRA for ESLs, SW-CP-AR project on EO ARTS for PDGS).

Information on Level 1B Swarm products can be found in [RD.4].

### 1.1 Current Operational configuration of monitored data:

- Processors Version: L1BOP 3.17, L2-Cat2 1.15.p6.
- L0 input products baseline: 02
- L1B baseline: MAGNET and PLASMA 04, ORBATT and ACCELE 03 (for definitions and description of the data baseline concept see <https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/swarm/data-access/product-baseline-definition>)
- Level 2 – Cat 2 baseline: EEF 01, IBI, FAC and TEC 02
- Input auxiliary files baseline: S/C A - CCDB 0013 (15/01/2017), S/C B – CCDB 0013 (31/10/2016), S/C C – CCDB 0013 (15/01/2017), ADF 0101
- MPPF-CVQ v.2.14.01

### 1.2 Reference documents

The following is a list of documents with a direct bearing on the content of this report. Where referenced in the text, these are identified as RD.n, where 'n' is the number in the list below:

- [RD.1] Sensor Performance, Products and Algorithms (SPPA), PGSI-GSOP-EOPG-TN-05-0025. Version 2.3.
- [RD.2] Swarm PDGS External DMC Interface Control Document, SW-ID-DS-GS-0001, Issue 3.2.
- [RD.3] Swarm MPPF-CVQ Monitoring Baseline Document, ST-ESA-SWARM-MBD-0001, Issue 1.7.
- [RD.4] Swarm Level 1B Product Definition, SW-RS-DSC-SY-0007, Issue 5.13.
- [RD.5] Swarm IDEAS Configuration Management Plan, IDEAS-SER-MGT-PLN-1081 v0.14.
- [RD.6] Swarm Quality Control Project Plan, IDEAS-SER-MGT-PLN-1071
- [RD.7] SW\_L1BOP\_status\_20141124\_MoM
- [RD.8] Planned Updates for Level 1b, SW-PL-DTU-GS-008, Rev: 1dC.
- [RD.9] IDEAS+ Swarm Weekly Report: 25/08/2014 – 31/08/2014, IDEAS+-SER-OQC-REP-2071\_SPPA\_SwarmWeeklyReport\_20140825\_20140831.pdf (ref. for SWL1L2DB-9)
- [RD.10] IDEAS+ Swarm Weekly Report: 29/09/2014 – 05/10/2014, IDEAS+-SER-OQC-REP-2071\_SPPA\_SwarmWeeklyReport\_20140929\_20141005.pdf (ref. for SW-IDEAS-34)
- [RD.11] IDEAS+ Swarm Weekly Report: 06/10/2014 – 12/10/2014, IDEAS+-SER-OQC-REP-2071\_SPPA\_SwarmWeeklyReport\_20141006\_20141012.pdf (ref. for SW-IDEAS-36)
- [RD.12] IDEAS+ Swarm Weekly Report: 20/10/2014 – 26/10/2014, IDEAS+-SER-OQC-REP-2071\_SPPA\_SwarmWeeklyReport\_20141020\_20141026.pdf (ref. for SW-IDEAS-40, GPS sync loss)
- [RD.13] IDEAS+ Swarm Weekly Report: 15/09/2014 – 21/09/2014, IDEAS+-SER-OQC-REP-2071\_SPPA\_SwarmWeeklyReport\_20140915\_20140921.pdf (ref. for SW-IDEAS-27)
- [RD.14] Swarm L1B 03.15 Validation Report, OSMV-OPMT-SRCP-RP-15-3385, Issue 1.3.
- [RD.15] IDEAS+ Swarm Weekly Report: 23/03/2015 – 29/03/2015, IDEAS+-SER-OQC-REP-2071\_SPPA\_SwarmWeeklyReport\_201513\_20150323\_20150329.pdf.
- [RD.16] SWARM Weekly Operations Report #76, SW-RP-ESC-FS-6172
- [RD.17] Olsen, N., H. Luhr, C.C. Finlay, T.J. Sabaka, I. Michaelis, J. Rauberg and L. Tøffner-Clausen, The CHAOS-4 geomagnetic field model, Geophys. J. Int. 197, 815–827, 2014
- [RD.18] IDEAS+-SER-IPF-PLN-2272, Swarm Level 1B Operational Processor Verification Plan, IDEAS+-SER-IPF-PLN-2272\_L1BOP\_316\_v1.5\_final.pdf

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[RD.19] SW-RP-SER-GS-010\_SPPA\_SwarmWeeklyReport\_201641\_20161010\_20161016.pdf



## 2. Summary of the observations

### 2.1 Changes in the general status of Swarm instruments and Level 1B products quality

During this week (09-15/01/2017), Swarm instruments generally behave nominally without major anomalies to report. The number of orbits in Active State of the EFFI-TII has been kept invariable, i.e., Swarm Alpha, six orbits, Swarm Bravo three orbits and Swarm Charlie, one orbit per week.

### 2.2 Plan for operational processor updates

**L1BOP:** In the next delivery of the L1BOP v03.19 (delivery date End-February 2017), the following changes will be implemented into the MAGNET and ORBATT processors:

- Change the data resampling used for the interpolation of the ASM measurements to UTC second because the present used in L1B data is removing a significant part of the high frequency content of the ASM data.
- Modification of the F\_error computation.
- Modification of detections of gaps in HK TM giving rise to among others gaps in MAGx\_CA.
- More robust handling of the leap second occurrence, and modification in timestamp sorting, in order to make the processor complete the run even in case of VFM on-board anomalies, that could imply a packet frequency greater than 1 Hz.
- Update of the STR data resampling a.o. eliminating recurrent, small jumps in 50 Hz attitude data.
- STR Inter-Boresight Angles correction model.
- An increase of the frequency of the STR L0 product from 1 Hz to 2 Hz
- Changes in the CCDB with inclusion of several new parameters is foreseen for many of the implementations above.

The activity of PLASMA cross-verification has been restarted and hopefully a fully cross-verified PLASMA processor will be included in the next delivery.

**L2 Cat-2:** In the next delivery of the L2 Cat-2 OP v1.17(delivery date End-February 2017) the following changes will be implemented:

- VTEC Implementation
- EEF adaption to L2PS EEF V2
- Implementation of the EEJ variable in EEF
- Update of embedded models in EEF processor
- Replacement of NAG library by GSL routines
- use modulus of vector measurement if scalar measurement is unavailable when subtracting core, lithospheric and external field contributions
- FAC Configuration File with time dependency

**PDGS evolution related activity:** Currently, the deployment in operations of L1BOP 3.18 and L2CAT2OP 1.16, including the update to the full Common Data Format processing schema, is foreseen for beginning of January 2016.

### 2.3 Quality Working Group and Cal/Val Coordination

Following the decisions of the 6<sup>th</sup> QWG in Edinburgh, these activities will be carried on in order to better understand:

- ❑ ASM-VFM Scalar Residuals:
  - Further work on the improvement of the dB<sub>sun</sub> correction model:
    - in order to de-correlate the VFM T<sub>EU</sub> and the Beta angles, it will be investigated the possibility of a test using the VFM Electronic Unit heater.
  - Further work on adjustment of the VFM pre-flight calibration parameter.
  - The root cause of the ASM-VFM residuals not yet identified:
    - on-ground testing with equipment/spares from development phase
    - New in orbit heater test: industries and users will be invited to comment the test before its implementation.
- ❑ ASM/VFM Inter-comparison analysis: Anomalies detected during the manoeuvres:
  - Have to be investigated if the anomaly is caused by something happening inside or outside the instrument/s
  - One hypothesis is: the ASM-ASM differences are mapped to the VFM during the calibration processing steps
  - More analysis has to be done on the pre-flight characterisation of the ASM after the changes on the bracket and cabling were changed before launch. Maybe a small y-oriented effect has not been fully captured.
  - The Leti team will be involved in order to see if it is possible to perform such test.
- ❑ EFI validation and investigations:
  - Validation of electron density and temperature by inter-comparison with ground based (ISR) and space borne (radio-occultation) measurements is at a good stage, with different datasets and approaches giving similar results. What now is needed is a wrap up of the different approaches and a summary work in order to finalize the results. Also very interesting and promising are validation approaches based on comparisons with models (e.g. IRI) and with the same parameters indirectly obtained from other Swarm datasets with some theoretical assumptions (especially electric field).
  - Some investigations are still on-going on Langmuir Probes side:
    - Understanding the correlation of the electron temperature spikes and the solar illumination on the solar panels.
    - S/C potential and el. Temp. hick-ups following a sweep mode activation: good progresses in modelling them, but root cause still unknown.
  - The TII processing has been simplified by the Univ. of Calgary team: only the cross-track flow is determined, which is more stable and reliable. Moreover a robust flagging of data based on the raw images characteristics is in progress.
- ❑ Data Distribution:
  - DTU have delivered the Swarm MAGx\_LR\_1B version 0501 products processed with prototype from BOM to end 2016 for all S/C. This dataset have been published on the /Advanced folder of the ESA ftp server. This dataset will contain the following changes:
    - the Star Tracker temperature correction
    - an update of Star Tracker interpolation and
    - an update of the vector data calibration and disturbance characterisation
 Due to technical issues in the processing of these first Baseline 05 data there are gaps not present in the Baseline 04 products. The gaps will be recovered in the next full mission data reprocessing.
  - ASM-V data: IPGP/LETI will deliver an updated version of the ASM vector data that will be available for all the users.
  - IRF will deliver the LP Sweep mode dataset to be distributed to Mission users only (end February 2017).

- University of Calgary will deliver a TII experimental dataset, based on the new processing scheme. This dataset will be distributed to Mission users only (mid February 2017).

## 2.4 Summary of observations for 2017, Week 2 (09/01 - 15/01)

During the monitored week the following events have been found and investigated:

- Change of CCDB parameters on 15<sup>th</sup> for Swarm A was nominal, while a minor issue was detected on Swarm Charlie. More information in Section 4.

## 3. Routine Quality control

### 3.1 Gaps analysis

- Two seconds gap in MAGB\_LR\_1B product in B variable on 12/01/2017 at 16:46:16 due to 1 VC4 frame gap.
- Several few seconds gaps in MAGx\_CA\_1B products throughout the week (gaps result from bug in the OP implementation, for details please see [RD.19]).

### 3.2 Orbit and Attitude Products

In Table 3-1 are listed events that have to be reported.

**Table 3-1:** List of events related to attitude and orbit products to be reported in the monitoring for 2017, Week 2: 09/01 - 15/01.

Observation ID	Description	Affected parameter	Sect. of Obs. Description	Sect. of Obs. Analysis

The relevant parameters that have been monitored are:

- Position difference between calculated Medium Accuracy orbits (**MODx\_SC\_1B**) and on-board solution (**GPSxNAV\_0**). Threshold values for such differences have not been assessed yet: we have just monitored the average values and maximum variations around the week. They are reported in tables in the sections below. In addition, some example plots are given from the HTML daily reports. For the time being we evaluated an anomaly should be raised if one (or more) of the following conditions occurs:
  - o The **average difference** on a given day exceeds the position accuracy requirement for the mission (1.5 m),
  - o The variability around the average is quite high: **standard deviation** threshold has been arbitrarily chosen to be twice the position accuracy requirement for the mission (2-sigma = 3 m).
  - o At least 4-5 spikes are observed on a given day, exceeding +/- 50 m.
- Visual inspection of Star Tracker characterisation flags (**STRxATT\_1B**)
- Deviation of the quaternion norm from unity (deviation threshold = +/- 10<sup>-9</sup>)
- Visual inspection of Euler Angles derived from quaternions.

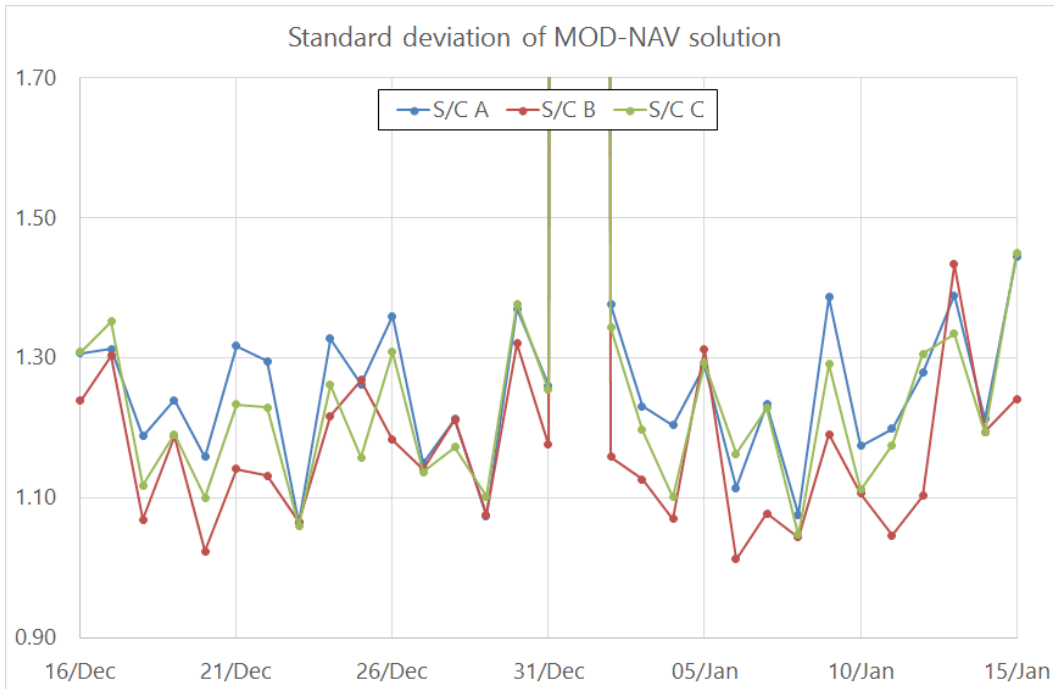
#### 3.2.1 Position Statistics

In Table 3-2, one can see the statistics of the differences between MOD and on-board solution positions for S/C A, B and C respectively. In the third column the maximum differences (maximum negative and maximum positive) are reported. The standard deviation is in the fourth column. Maxima, minima and standard deviations usually refer to the Z component that is often the most disturbed; in case another component is most affected, it will be specified in parentheses. Figure 3-1 shows a cumulative trend of the maximum daily standard deviation for the past 30 days

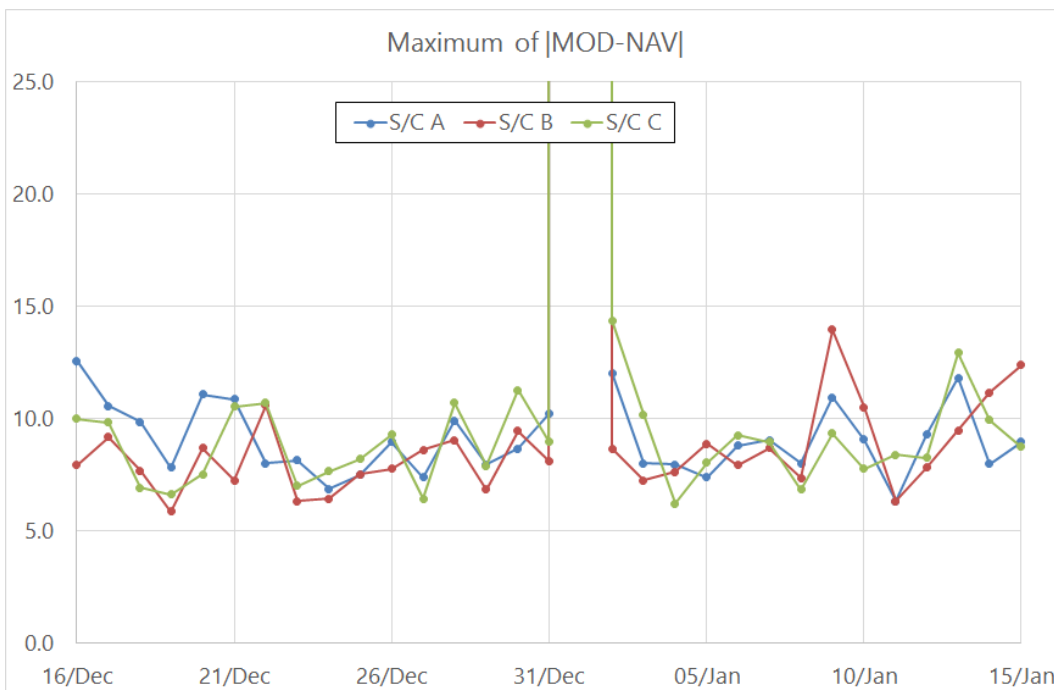
of operations of the MOD-NAV difference, while Figure 3-2 shows the daily maximum difference, in absolute value, of the MOD-NAV difference, always for the past 30 days of operations.

**Table 3-2:** Swarm A, B and C, difference between MOD and on-board solution positions. If not specified maximum difference and standard deviation refers to the Z-axis.

Swarm A, 09/01 - 15/01, Position difference					
Day	Average difference (m)	Maximum difference (m)		Standard deviation (m)	Notes
09/01	0.17	-9.4	11	1.39	
10/01	0.11	-6.6	9.1	1.17	
11/01	0.03	-6.3	5.5	1.2	
12/01	0.05	-9.3	8.8	1.28	
13/01	0.11	-11.8	7.4 (Y)	1.39	
14/01	0.11	-7.9	8 (X)	1.21	
15/01	0.08	-9	8.8	1.44	
Swarm B, 09/01 - 15/01, Position difference					
Day	Average difference (m)	Maximum difference (m)		Standard deviation (m)	Notes
09/01	0.07	-5.5	14	1.19	
10/01	0.12	-10.5	5.3	1.11	
11/01	0.07	-6.3	4.6	1.05	
12/01	0.08	-7.8	4.9	1.1	
13/01	0.07	-8.7	9.5	1.43	
14/01	0.11	-6	11.2	1.19	
15/01	0.14	-12.4	8.7	1.24	
Swarm C, 09/01 - 15/01, Position difference					
Day	Average difference (m)	Maximum difference (m)		Standard deviation (m)	Notes
09/01	0.17	-7.7	9.3	1.29	
10/01	0.11	-5.3	7.8	1.11	
11/01	0.04	-8.4	5.2	1.17	
12/01	0.09	-8.2	6.5	1.31	
13/01	0.11	-12.9	7	1.33	
14/01	0.13	-10	6.3	1.19	
15/01	0.12	-8	8.8	1.45	



**Figure 3-1:** Plot of the standard deviation of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.



**Figure 3-2:** Plot of the maximum difference of the absolute value of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.

3.2.1.1 Swarm A

Below is presented plot of MOD-NAV differences for S/C A, taken at the beginning of the week (09/01, Figure 3-3). From top to bottom, the plots show of MOD-NAV differences in ITFR reference frame: on X, Y and Z-axis respectively, differences are given in [m].

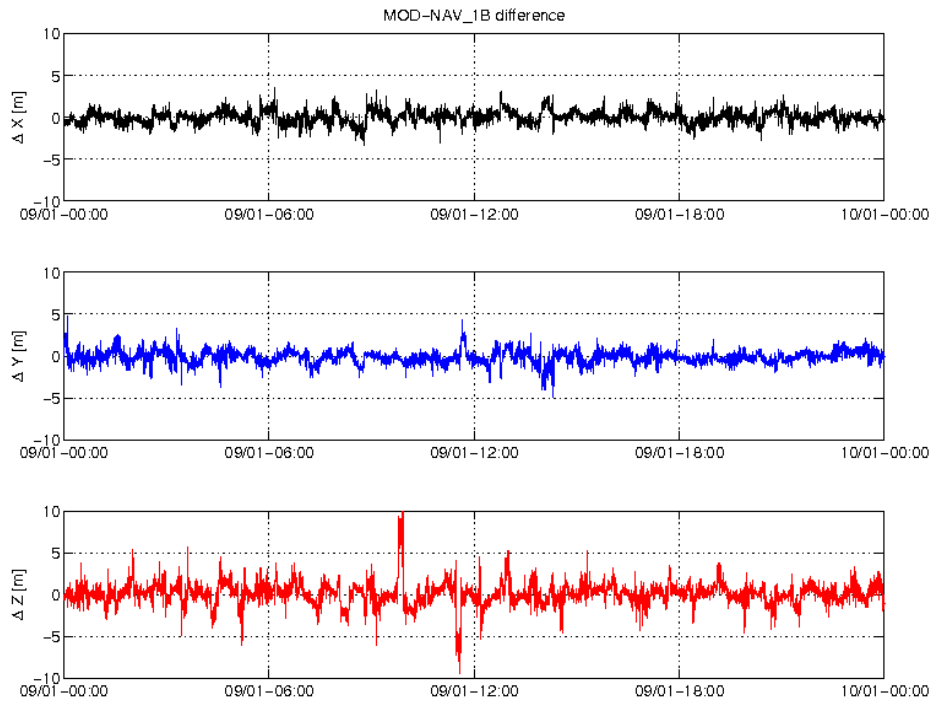


Figure 3-3: Difference MOD-GPSNAV, S/C A, 09/01. From top to bottom: X, Y and Z-axis

3.2.1.2 Swarm B

Below is presented plot of MOD-NAV differences for S/C B, taken at the beginning of the week (09/01, Figure 3-4). From top to bottom, the plots show of MOD-NAV differences in ITFR reference frame: on X, Y and Z-axis respectively, differences are given in [m].

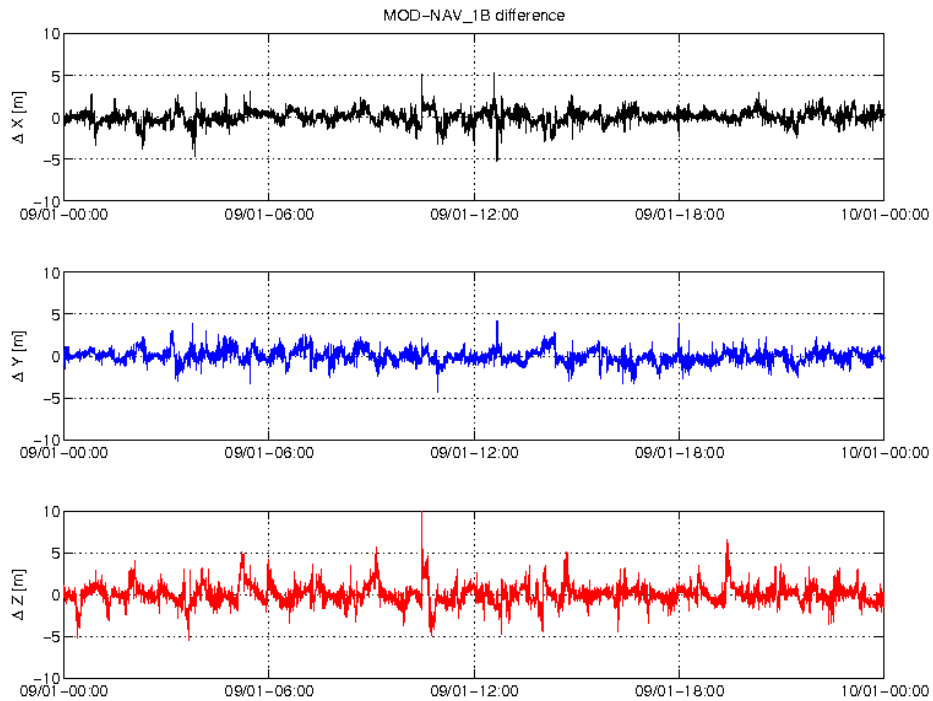
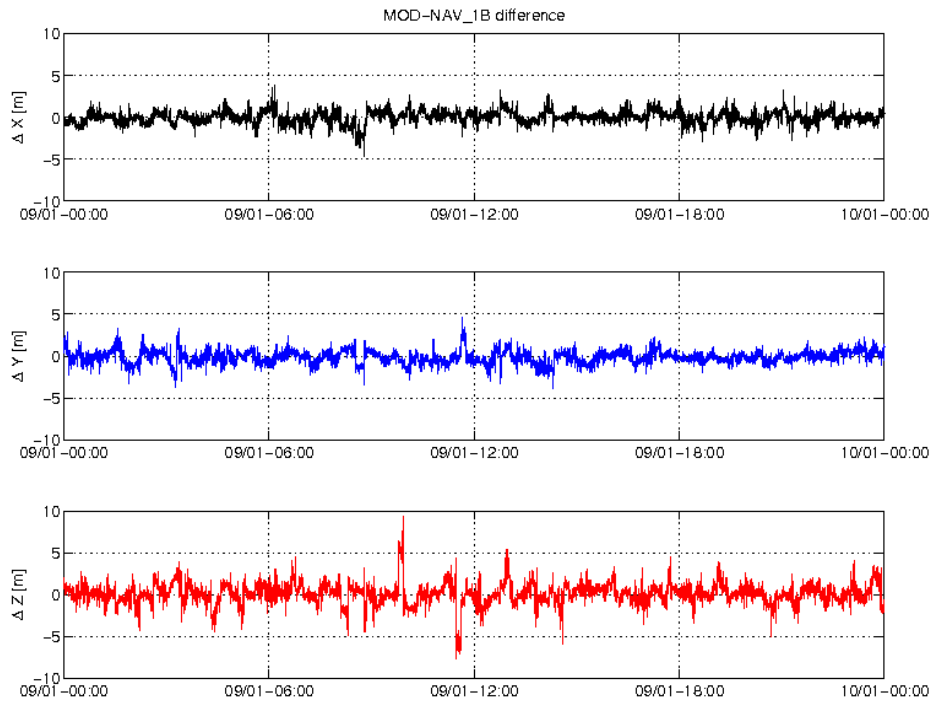


Figure 3-4: Difference MOD-GPSNAV, S/C B, 09/01. From top to bottom: X, Y and Z-axis



### 3.2.1.3 Swarm C

Below is presented plot of MOD-NAV differences for S/C C, taken at the beginning of the week (09/01, Figure 3-5). From top to bottom, the plots show of MOD-NAV differences in ITFR reference frame: on X, Y and Z-axis respectively, differences are given in [m].



**Figure 3-5:** Difference MOD-GPSNAV, S/C C, 09/01. From top to bottom: X, Y and Z-axis

## 3.2.2 Attitude observations

### 3.2.2.1 Swarm A

Nothing to report.

### 3.2.2.2 Swarm B

Nothing to report.

### 3.2.2.3 Swarm C

Nothing to report.

## 3.3 Magnetic Products

For the magnetic products, the weekly monitoring consists in:

- ASM instrument monitoring: quartz frequency (nominal range: [2.949E7 – 2.950E7] Hz) and ASM temperature (temperature range shall be: [-30;+50] °C, Rel. Variation shall not exceed: 0.1 °C/sec).

- VFM instrument monitoring: temperatures (Rel. Variation shall not exceed: 0.1 °C/sec).
- Visual inspection of daily time series of magnetic field intensity  $F$ ,  $B_{NEC}$  and  $B_{VFM}$ . Looking for gaps (or zero values in case of  $MAGx_{LR\_1B}$  products), out-of-threshold values (i.e. exceeding +/- 60000 nT), and other strange features. Map plots of  $F$  and  $B_{NEC}$  for the whole week are then displayed.
- Monitoring of the ASM-VFM known anomaly: visual inspection of  $|B_{VFM}| - F$  taken from  $MAGx_{CA\_1B}$  products and recording of daily maximum variations and standard deviations. If +/- 1 nT are exceeded on a given day, an alert is raised. Map plots of the residuals are shown along with weekly time series of the residuals with and without the "dB\_Sun" correction: in fact, at least a part of the discrepancies found in the measurements between ASM and VFM are modelled through a stray field (dB\_Sun) that is a function of the orientation of the VFM wrt Sun.
- Comparison of magnetic data ( $B_{NEC}$ ) with a model (Chaos5).
- Second derivative of vector field in VFM and NEC frame. Only measurement points within  $\pm 10^\circ$  latitude are considered, and values above 100 nT/s<sup>2</sup> are considered out of threshold.
- 5-min correlations between S/C A and S/C C  $B_{NEC}$  measurements.
- Differences between S/C A and C,  $B_{NEC}$  measurements. Values above 8000 nT are considered out of threshold.

In Table 3-3 are listed events that have to be reported.

**Table 3-3:** List of events related to magnetic products to be reported in the monitoring for 2017, Week 2: 09/01 - 15/01.

Observation ID	Description	Affected parameter	Sect. of Obs. Description	Sect. of Obs. Analysis
SW-IDEAS-63	OBS_ROUTINE: MAGx_CA_1B gaps	MAGx_CA_1B	3.1	NA

### 3.3.1 VFM-ASM anomaly

- S/C A – no violation detected.
- S/C B – violation of:
  - o VFM-ASM residuals threshold on-09/01, 10/01, 11/01, 12/01, 13/01;
  - o mean value of residuals threshold on 09/01, 10/01;
  - o standard deviation of residuals threshold on 09/01.

#### 3.3.1.1 ASM-VFM difference statistics

In Table 3-4, one can see the statistics of the differences between magnetic field absolute value measured by ASM and by VFM. In the second and third column are reported the maximum differences, maximum negative and maximum positive respectively. The standard deviation is in the fourth column.

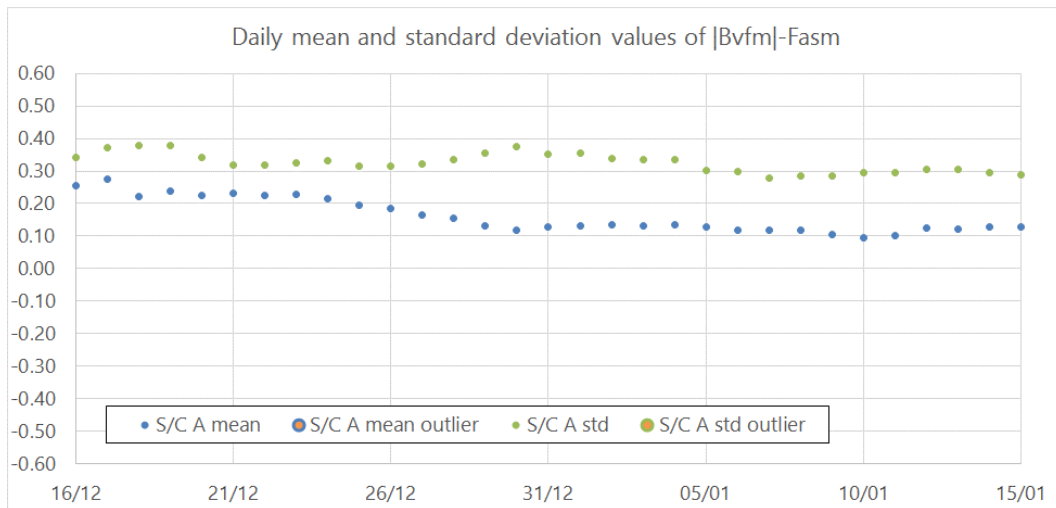
The ASM-VFM difference is defined as follow:

$$dF = |B_{VFM}| - F_{ASM}$$

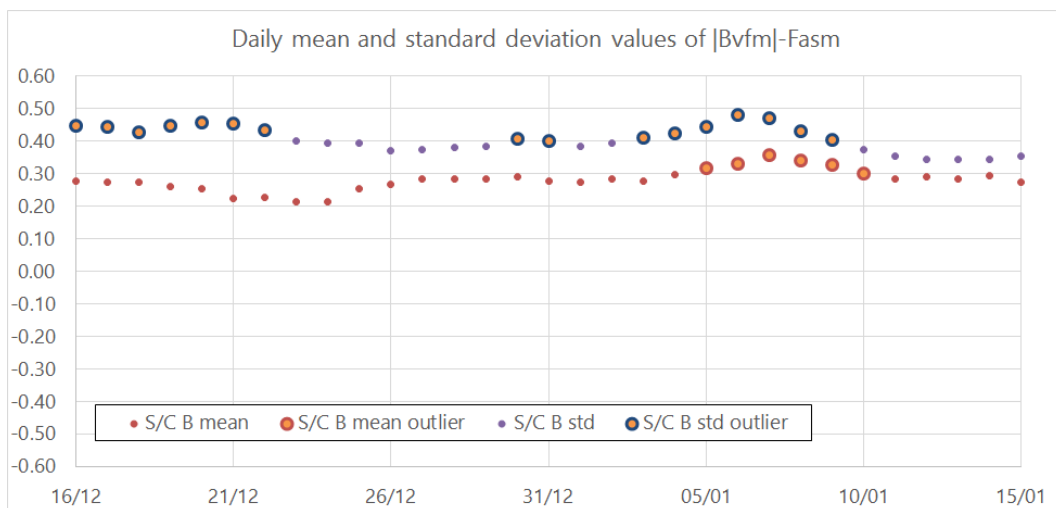
Figure 3-6 and Figure 3-7 show the daily mean (circles) and standard deviation (crosses) of dF of the last month for Swarm A and Swarm B respectively.

**Table 3-4:** Swarm A and B, difference between absolute value of magnetic field measured by ASM and by VFM.

Swarm A, 09/01 - 15/01, ASM-VFM difference					
Day	Max (nT)	Min (nT)	Standard deviation (nT)	Mean (nT)	Notes
09/01	0.68	-0.61	0.29	0.105	
10/01	0.77	-0.6	0.3	0.096	
11/01	0.69	-0.58	0.29	0.1	
12/01	0.7	-0.69	0.3	0.124	
13/01	0.76	-0.72	0.3	0.122	
14/01	0.72	-0.82	0.3	0.129	
15/01	0.72	-0.77	0.29	0.129	
Swarm B, 09/01 - 15/01, ASM-VFM difference					
Day	Max (nT)	Min (nT)	Standard deviation (nT)	Mean (nT)	Notes
09/01	<b>1.23</b>	-0.84	<b>0.4</b>	<b>0.328</b>	
10/01	<b>1.24</b>	-0.75	0.37	<b>0.301</b>	
11/01	<b>1.19</b>	-0.69	0.35	0.283	
12/01	<b>1.12</b>	-0.63	0.34	0.291	
13/01	<b>1.06</b>	-0.66	0.34	0.285	
14/01	0.98	-0.7	0.34	0.293	
15/01	0.95	-0.74	0.35	0.274	



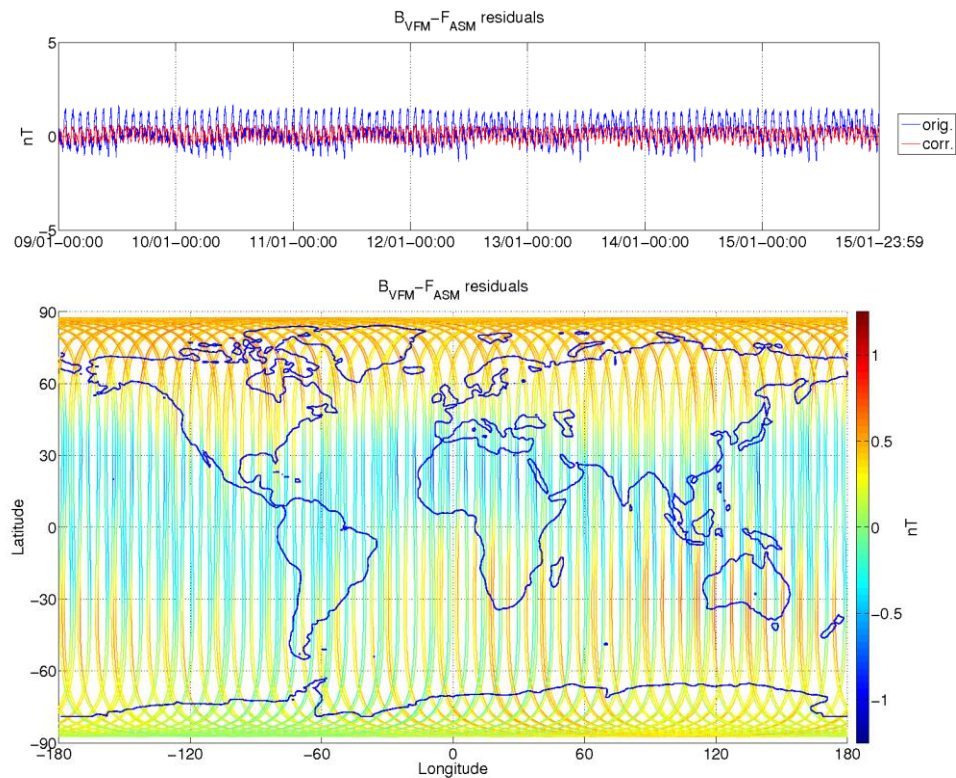
**Figure 3-6:** Daily mean and standard deviation values of ASM-VFM residuals (defined as  $dF = |B_{VFM}| - F_{ASM}$ ) for S/C A.



**Figure 3-7:** Daily mean and standard deviation values of ASM-VFM residuals (defined as  $dF = |B_{VFM}| - F_{ASM}$ ) for S/C B.

### 3.3.1.2 Swarm A

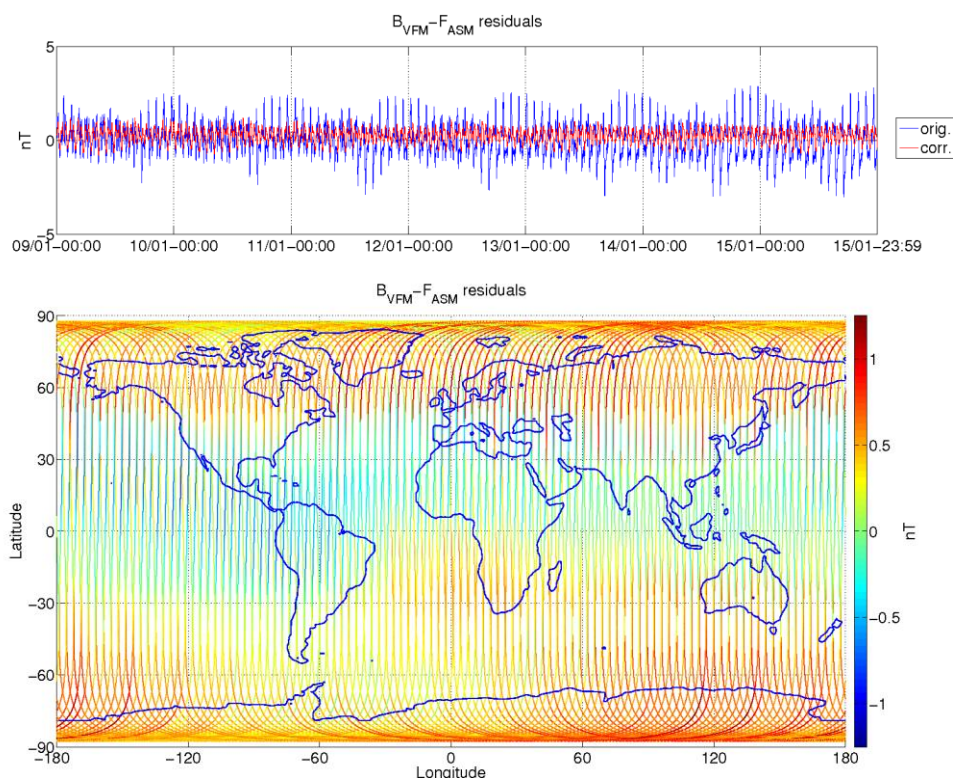
The daily peak-to-peak difference around the week stays within  $[-0.82 - 0.77]$  nT. Below follow two plots of such differences for current week (Figure 3-8).



**Figure 3-8:** ASM-VFM residuals for S/C A, during monitoring period 09/01-15/01. In top figure are plotted: difference between  $|B_{VFM}|$  and  $F_{ASM}$  (without  $dB_{Sun}$  correction) (blue colour), and the residuals with  $dB_{Sun}$  corrections (red colour). In bottom figure residuals are presented on the world map.

### 3.3.1.3 Swarm B

The daily peak-to-peak difference around the week stays within  $[-0.84 \ 1.24]$  nT. Below follow two plots of such differences for current week (Figure 3-9).



**Figure 3-9:** ASM-VFM residuals for S/C B, during monitoring period 09/01-15/01. In top figure are plotted: difference between  $|B_{VFM}|$  and  $F_{ASM}$  (without  $dB_{Sun}$  correction) (blue colour), and the residuals with  $dB_{Sun}$  corrections (red colour). In bottom figure residuals are presented on the world map.

### 3.3.1.4 Swarm C

No data because ASM is switched off.

### 3.3.2 ASM Instrument parameters: quartz frequency and ASM temperature (ASMAVEC\_0)

For S/C A and B, the temperature and quartz frequency behaved as expected.

### 3.3.3 VFM Instrument parameters: VFM temperatures (MAG\_CA)

The VFM instrument parameters important for monitoring the instrument health are the VFM sensor temperatures:  $T_{CDC}$ ,  $T_{CSC}$  and  $T_{EU}$ .

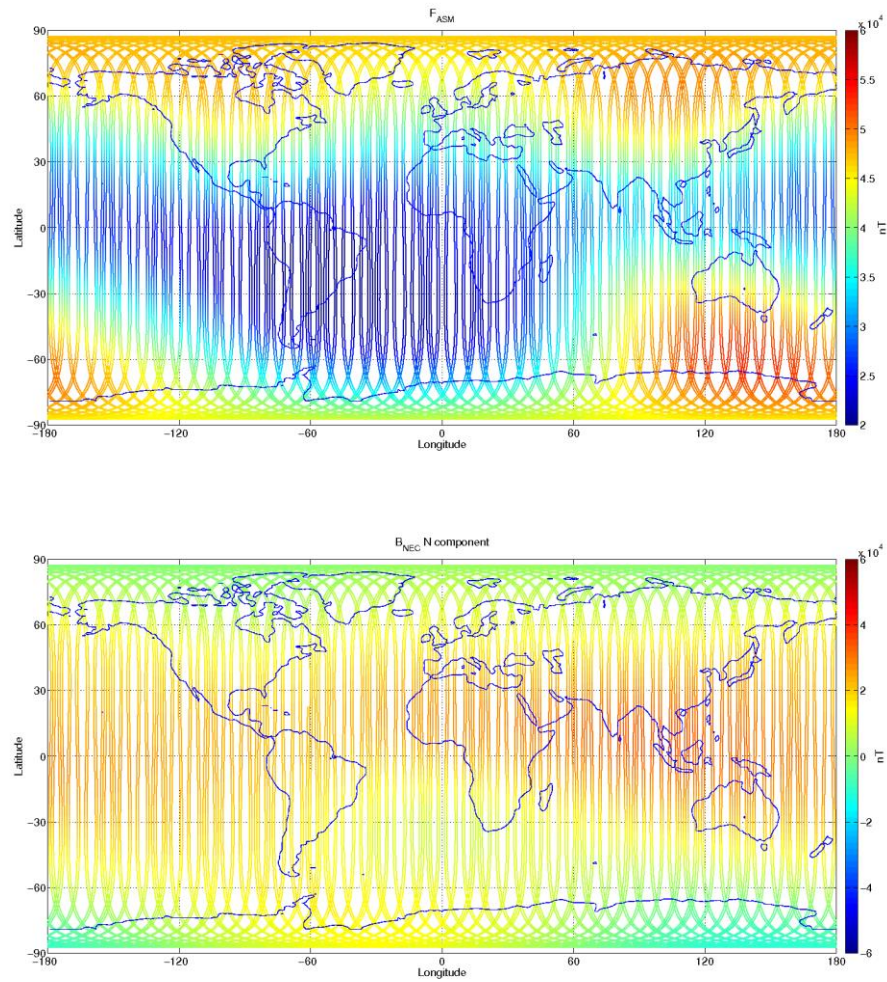
For S/C A, B and C, for reported period, the temperatures behaved as expected.

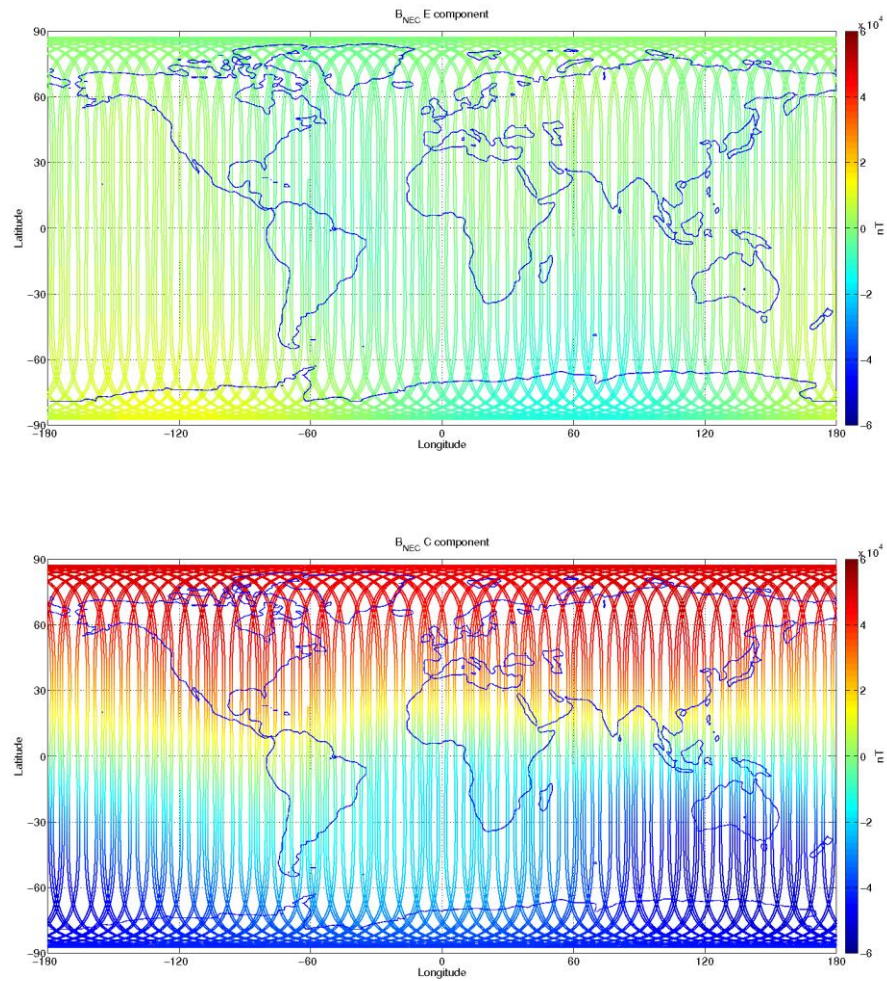


### 3.3.4 Magnetic time series visual inspection

#### 3.3.4.1 Swarm A

Map plots of magnetic field measurement for week 2 for S/C A can be seen in Figure 3-10 below.



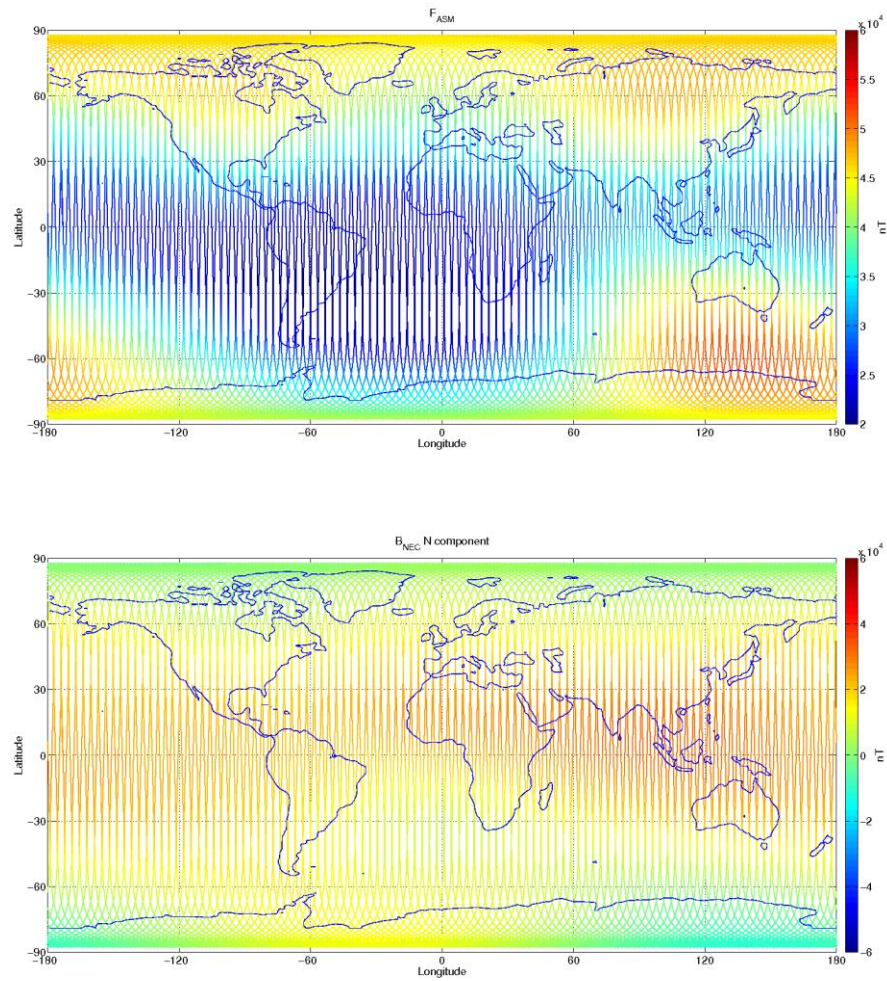


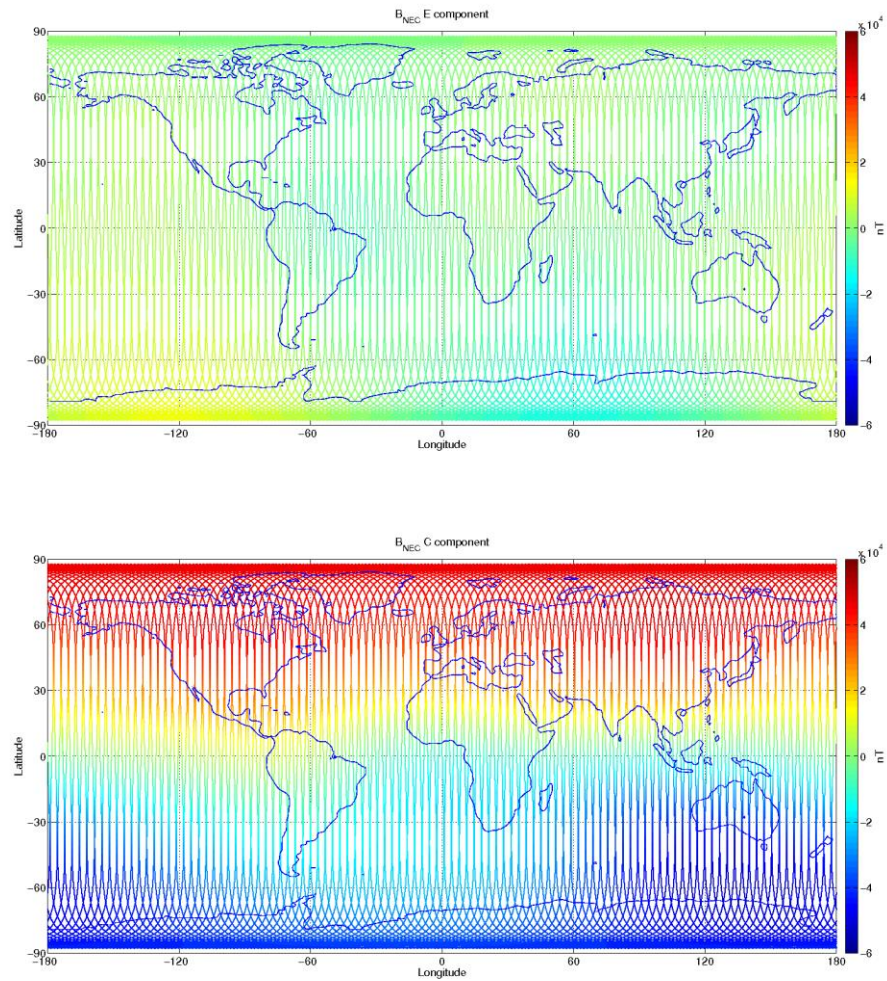
**Figure 3-10:** S/C A, world map plots of the geomagnetic field and components measured during monitoring period 09/01-15/01. From top to bottom: F-magnetic field from ASM measurement, B<sub>NEC</sub> components (North, East, and Centre) of magnetic field from VFM measurement.



### 3.3.4.2 Swarm B

Map plots of magnetic field measurement for week 2 for S/C B can be seen in Figure 3-11 below.



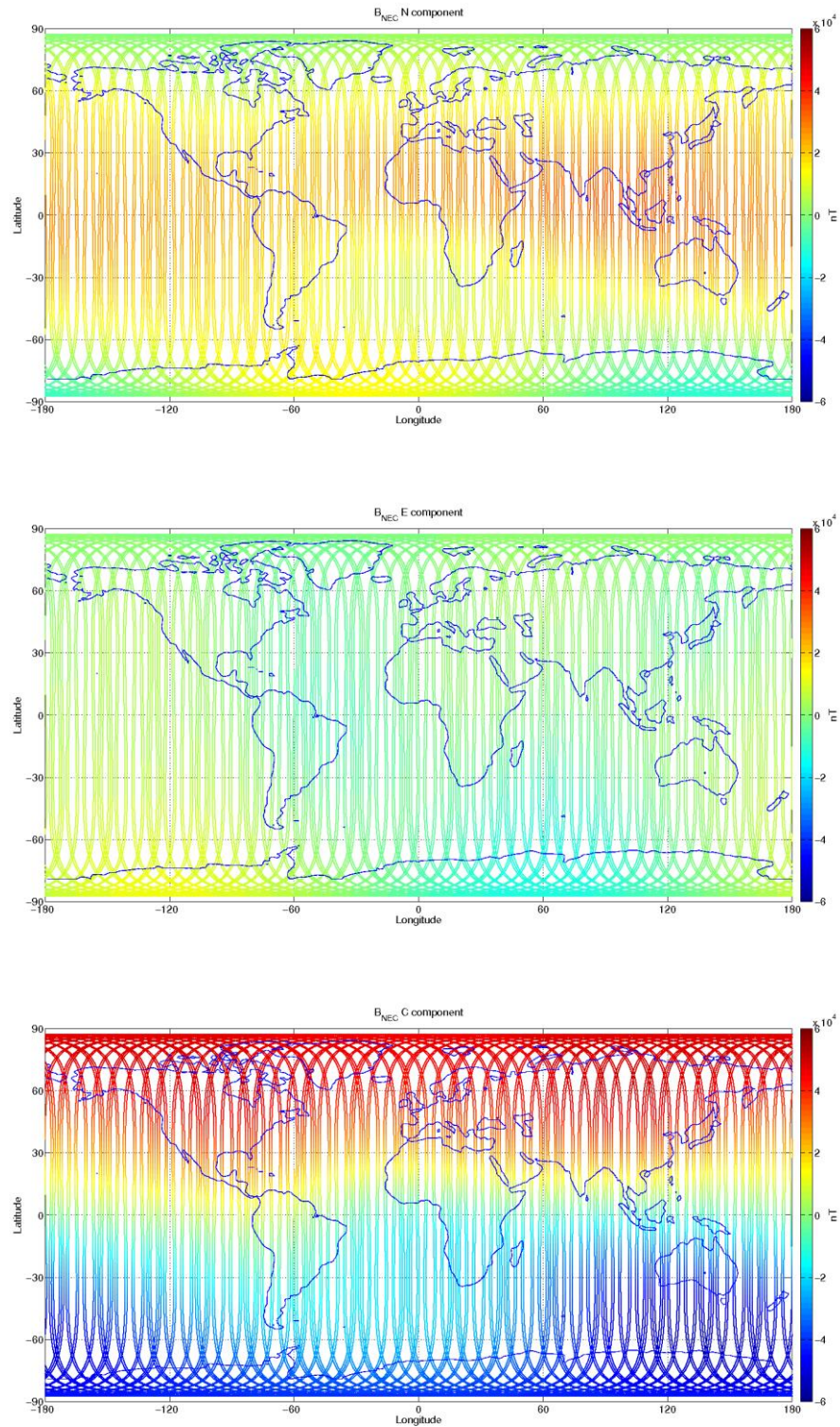


**Figure 3-11:** S/C B, world map plots of the geomagnetic field and components measured during monitoring period 09/01-15/01. From top to bottom: F-magnetic field from ASM measurement,  $B_{NEC}$  components (North, East, and Centre) of magnetic field from VFM measurement.



### 3.3.4.3 Swarm C

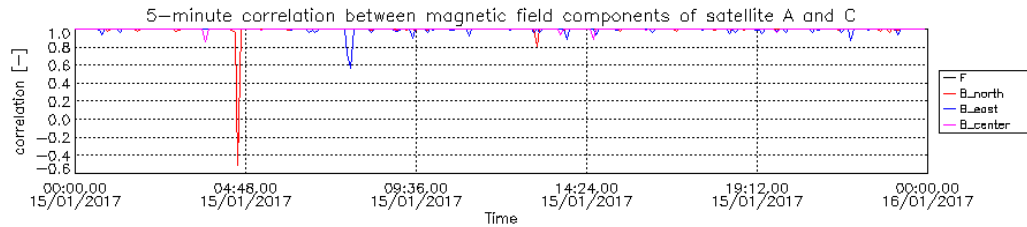
Map plots of magnetic field measurement for week 2 for S/C C can be seen in Figure 3-12.



**Figure 3-12:** S/C C, world map plots of the geomagnetic field and components measured during monitoring period 09/01-15/01. From top to bottom:  $B_{NEC}$  components (North, East, and Centre) of magnetic field from VFM measurement.

### 3.3.5 S/C A and C magnetic correlation

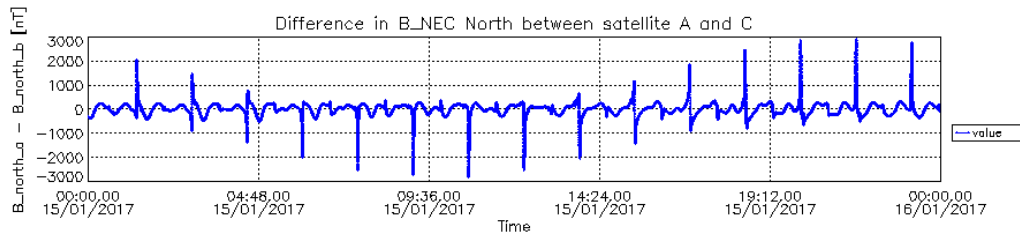
In the plot below is shown the correlation in 5-minutes intervals of magnetic data between satellite A and C.  $B_{north}$ ,  $B_{east}$ , and  $B_{center}$  are the components of the magnetic field vector in NEC frame.



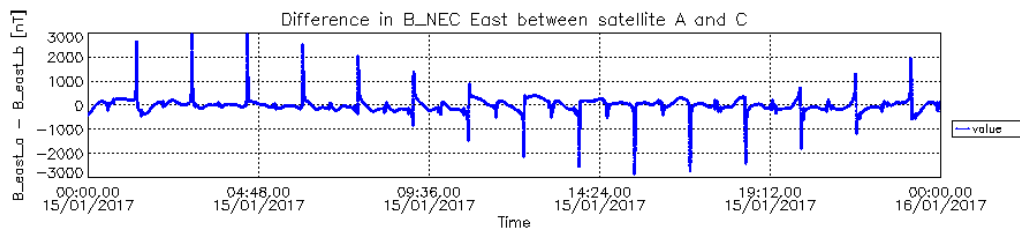
**Figure 3-13:** Correlation in magnetic data between satellite A and C for  $B_{north}$ ,  $B_{east}$ , and  $B_{center}$  components of  $B_{NEC}$  are the components of the magnetic field vector in NEC frame

### 3.3.6 S/C A and C magnetic difference

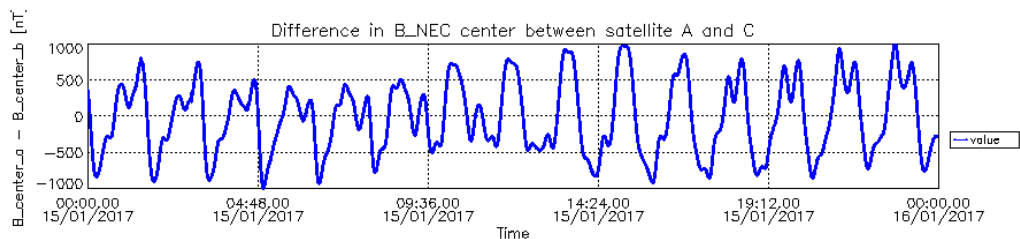
The next three plots show the differences in magnetic data between satellite A and C. Threshold is set to 8 000 nT for each component.



**Figure 3-14:** Difference in  $B_{NEC}$  North component between S/C A and S/C C.



**Figure 3-15:** Difference in  $B_{NEC}$  East component between S/C A and S/C C.



**Figure 3-16:** Difference in  $B_{NEC}$  Center component between S/C A and S/C C.

### 3.3.7 $B_{NEC}$ vs Chaos5 model residuals

The magnetic field measurement is compared to magnetic field estimated from the Chaos5 global geomagnetic field model (only Core and Crustal contributions). Currently in the monitoring routines the external contribution based on Dst index is not taken into account.

Figure 3-17, Figure 3-19 and Figure 3-21 show field residuals  $\Delta B = B_{NEC} - B_{Chaos}$  (all versus co-latitude in degrees), from top to bottom: 1)  $B_r$ , 2)  $B_\theta$  and 3)  $B_\phi$ .

As a general feature one can see the field residuals to be steady and usually below 50 nT at low and middle latitudes, up to  $|55| - |60|$  degrees; then the residual increases at high latitudes because the Chaos model does not take into account the contribution from the external field ([RD.17]).

Figure 3-18, Figure 3-20 and Figure 3-22 show, from top to bottom, the time series on 09/01 of: (1-2-3) residuals of  $B_{NEC} - B_{Chaos}$  by components, related to S/C A, B and C respectively.

The component most affected by residual spikes and variations is  $B_{\theta, NEC}$ , i.e. the component that shows the variations of the field wrt to co-latitude. At high latitudes, the order of magnitude of the variability is about  $\pm 200$  nT.

#### 3.3.7.1 Swarm A

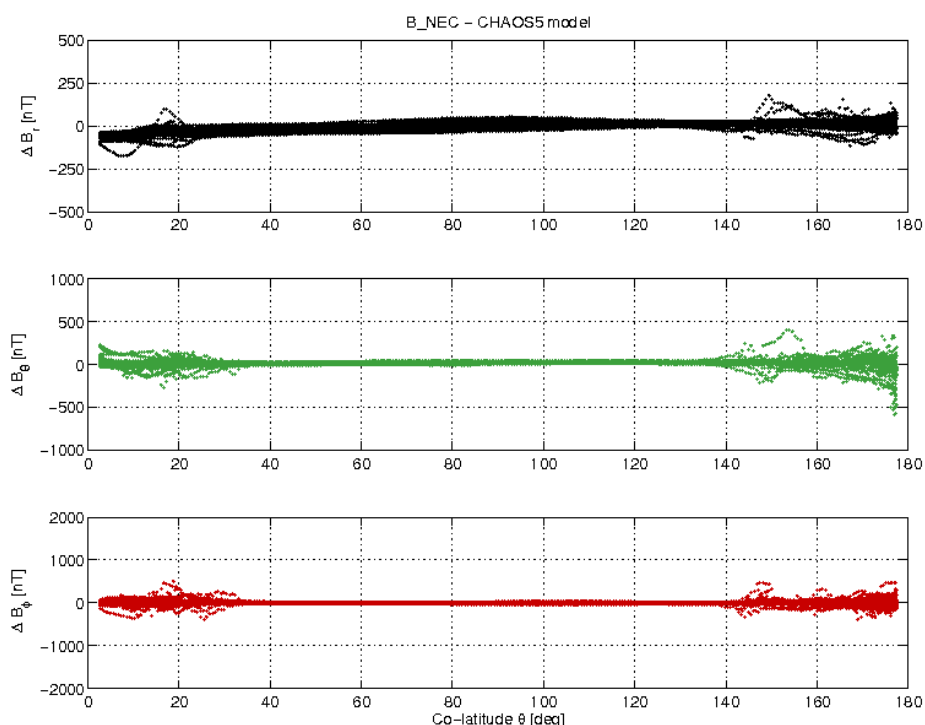
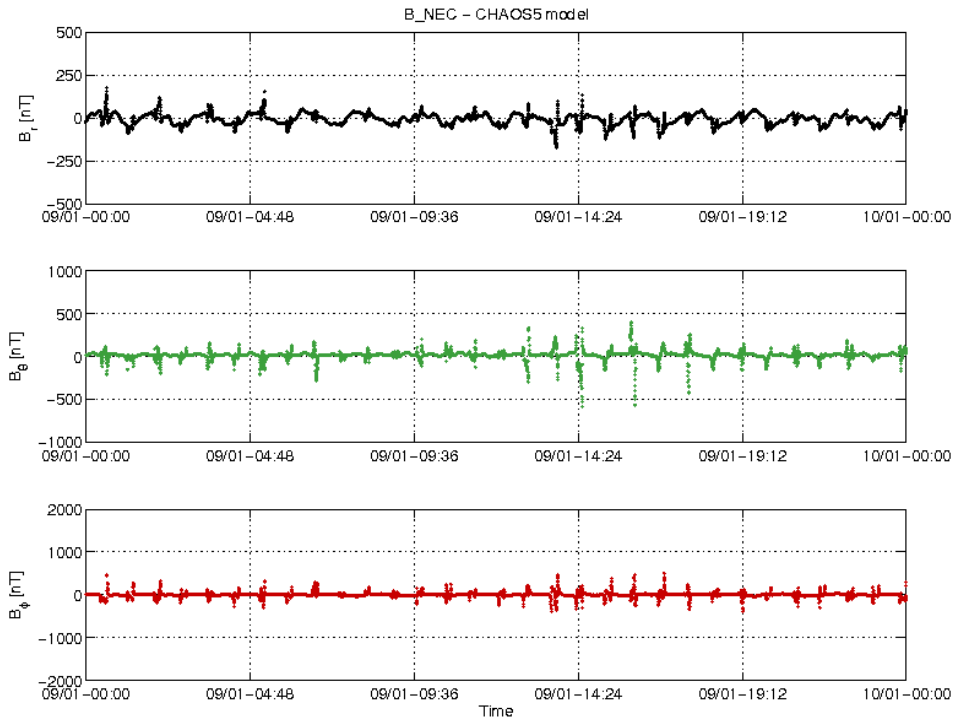


Figure 3-17: S/C A day 09/01  $B_{NEC} - B_{Chaos}$  vs colatitude.



**Figure 3-18:** S/C A day 09/01: time series of  $B_{NEC} - B_{Chaos}$  residuals.

3.3.7.2 Swarm B

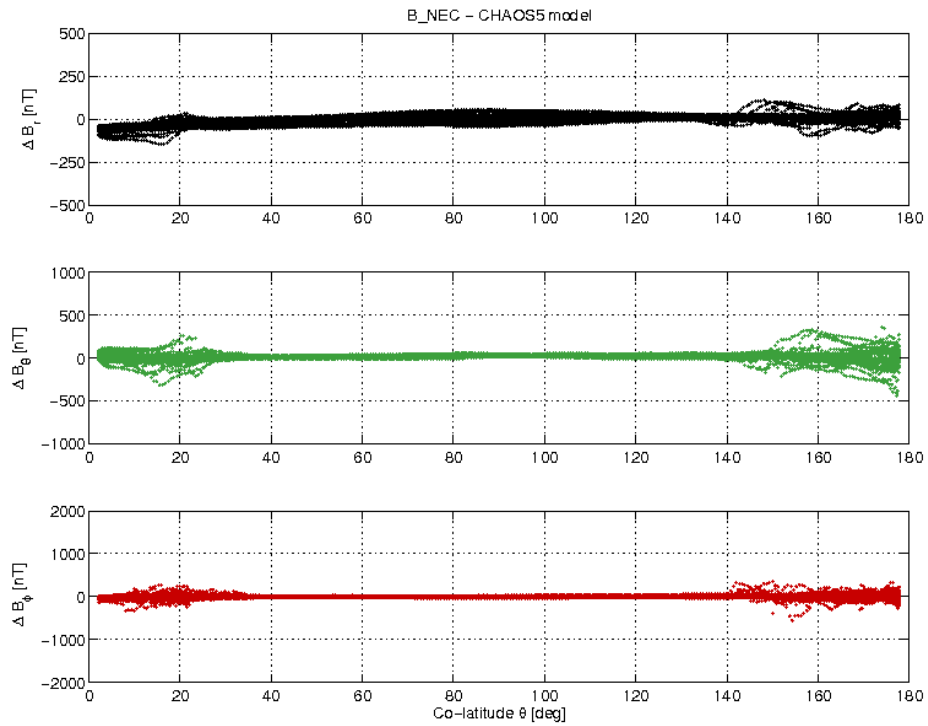


Figure 3-19: S/C B day 09/01  $B_{NEC} - B_{Chaos}$  difference vs colatitude.

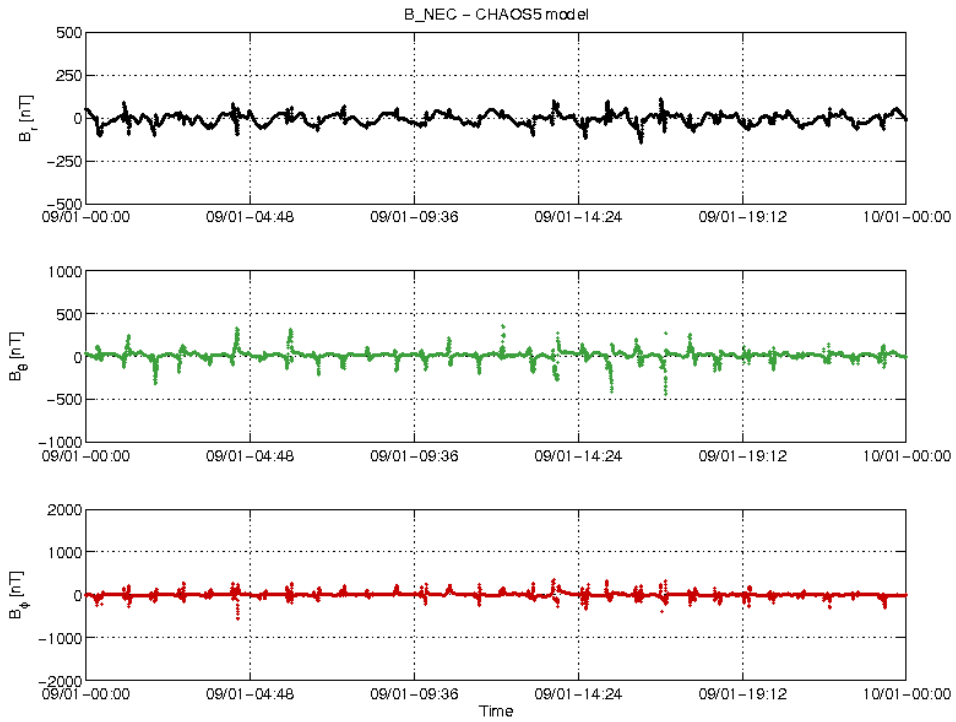


Figure 3-20: S/C B day 09/01 time series of  $B_{NEC} - B_{Chaos}$  residuals.



3.3.7.3 Swarm C

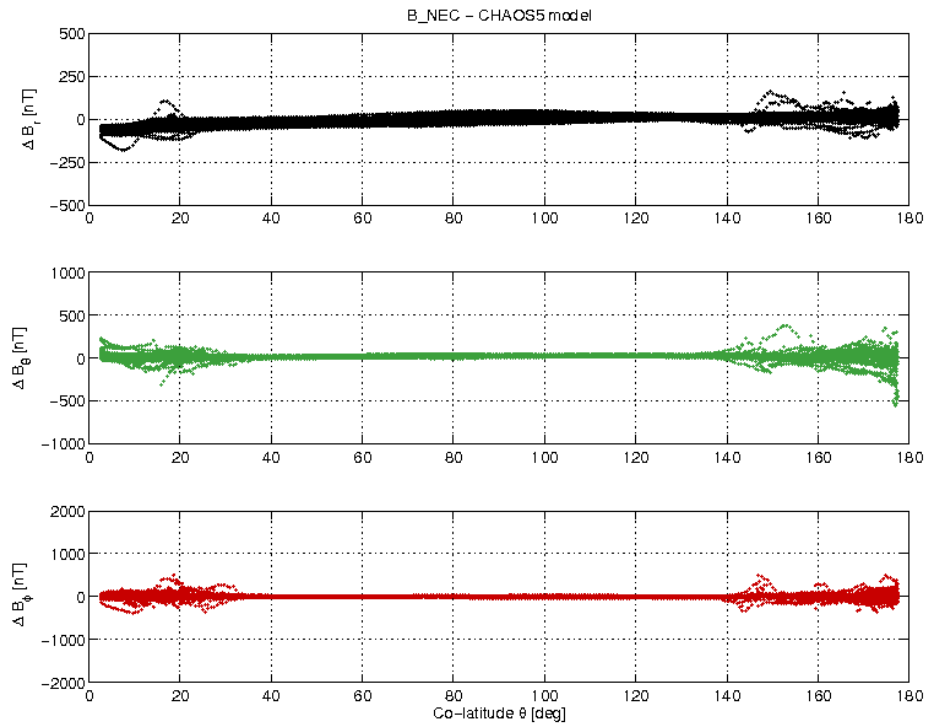


Figure 3-21: S/C C day 09/01  $B_{NEC} - B_{Chaos}$  difference vs colatitude.

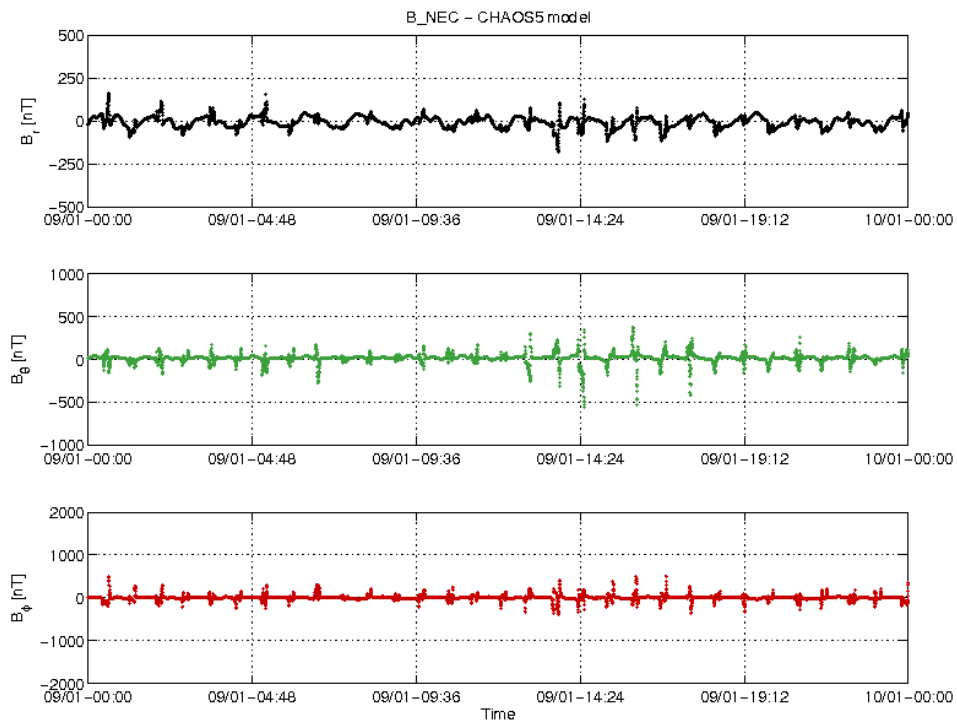


Figure 3-22: S/C C day 09/01 time series of  $B_{NEC} - B_{Chaos}$  residuals.

### 3.3.8 Second derivative of $B_{NEC}$ and $B_{VFM}$

The second derivative of the vector magnetic field measurements in both VFM and NEC frame has been performed on 50Hz data (MAGx\_HR\_1B). In this analysis only measurement points within  $\pm 10^\circ$  latitude have been considered. Figure 3-23, Figure 3-24 and Figure 3-25 show the daily standard deviation of the second derivative of BVFM of the last month for S/C A, B, and C respectively. Second derivative of  $B_{NEC}$  is not shown due to artificial spikes introduced during quaternions interpolation from 1Hz to 50Hz.

3.3.8.1 Swarm A

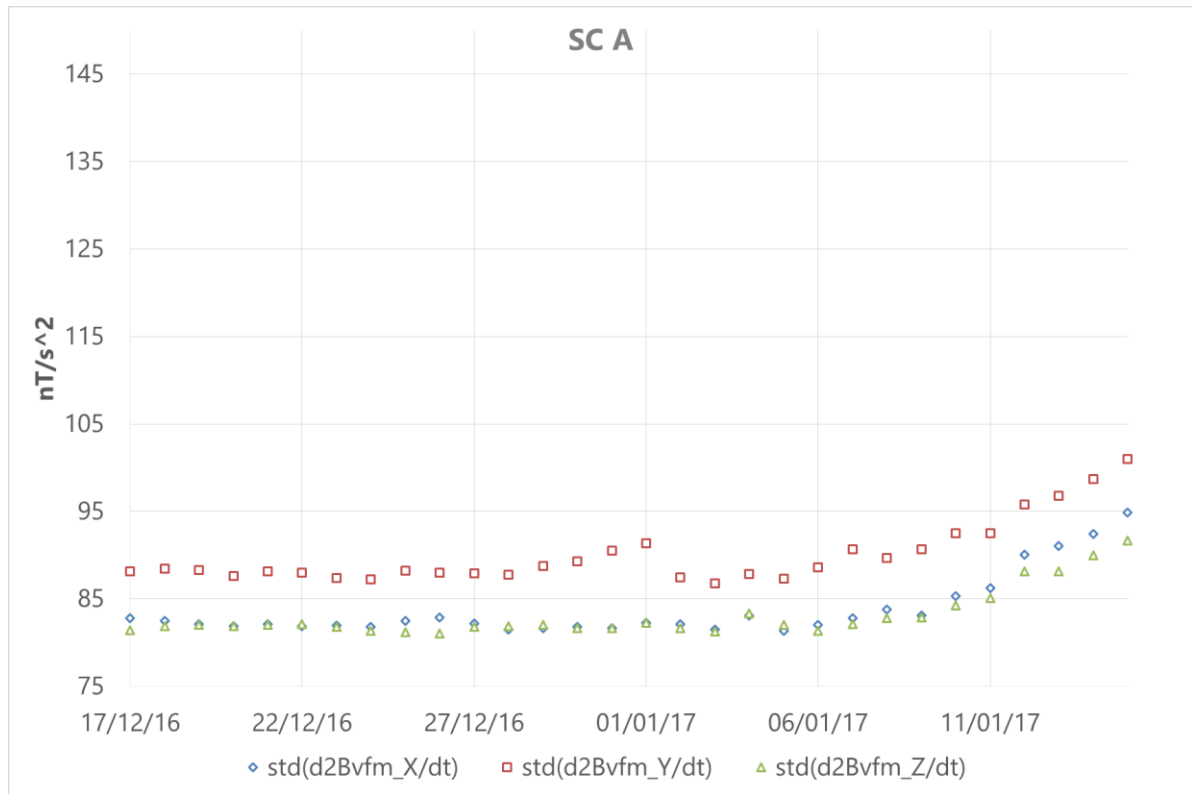


Figure 3-23: Plot of standard deviation of B components in VFM frames.

3.3.8.2 Swarm B

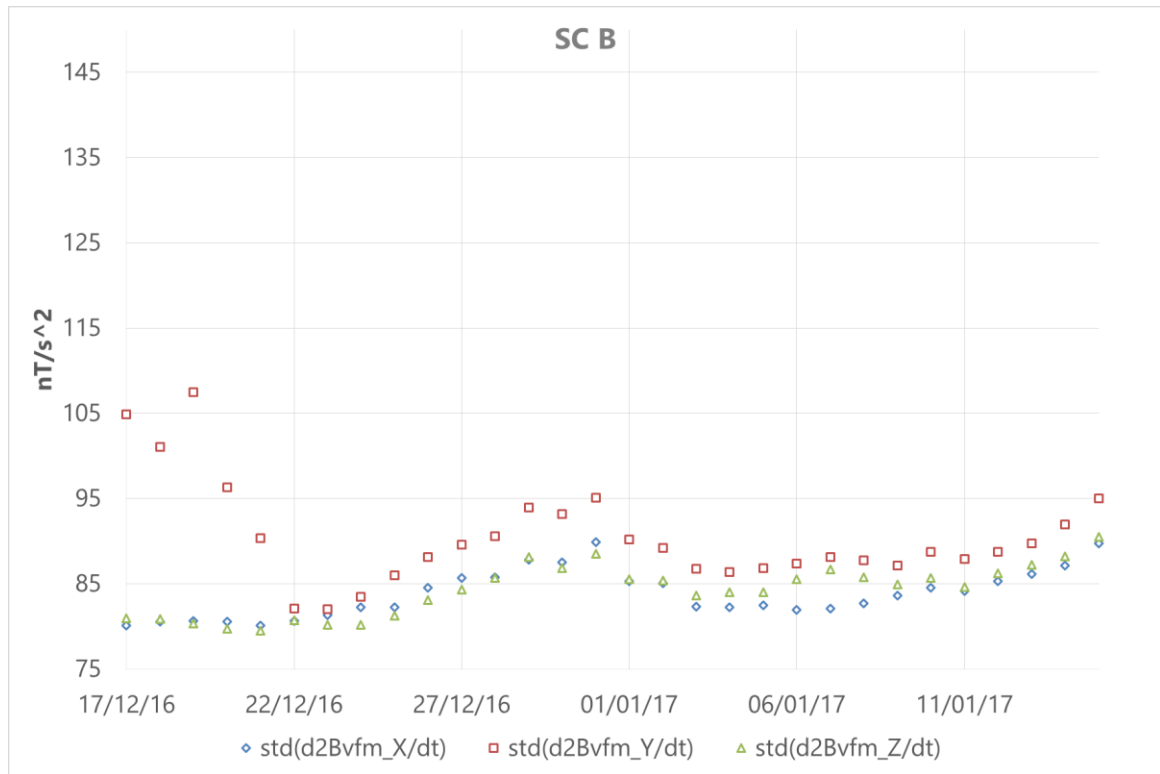


Figure 3-24: Plot of standard deviation of B components in VFM frames.

3.3.8.3 Swarm C

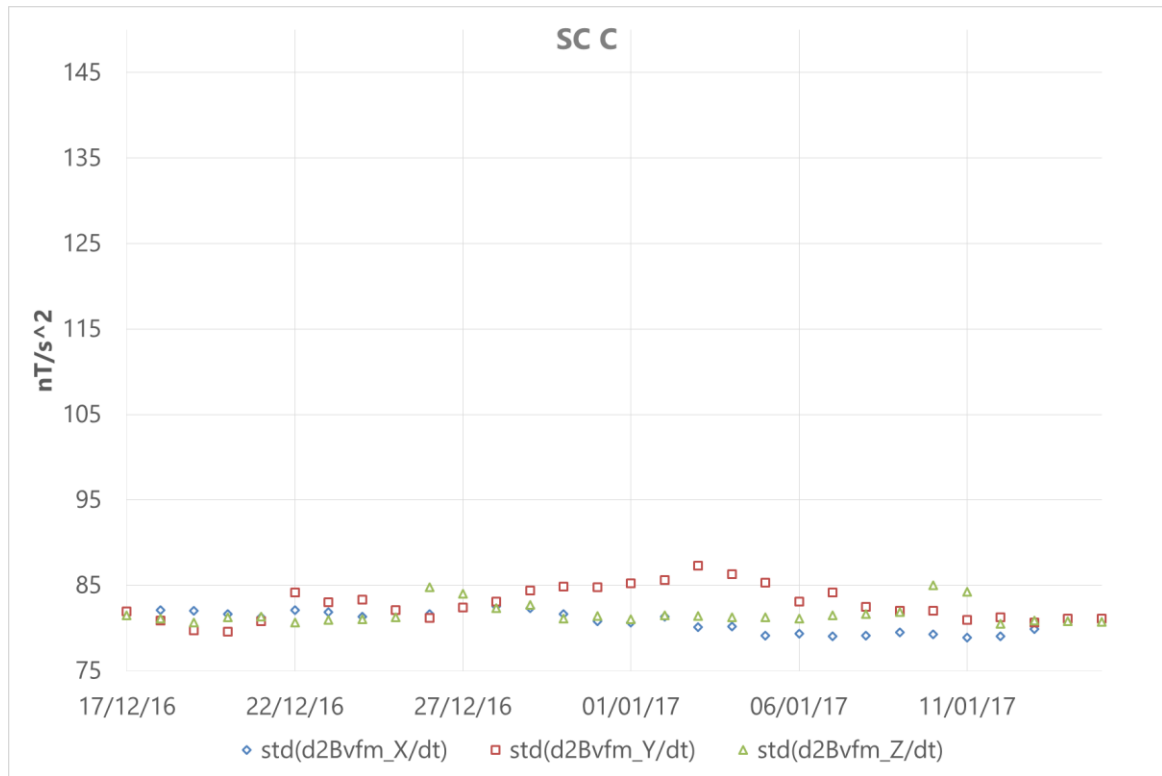
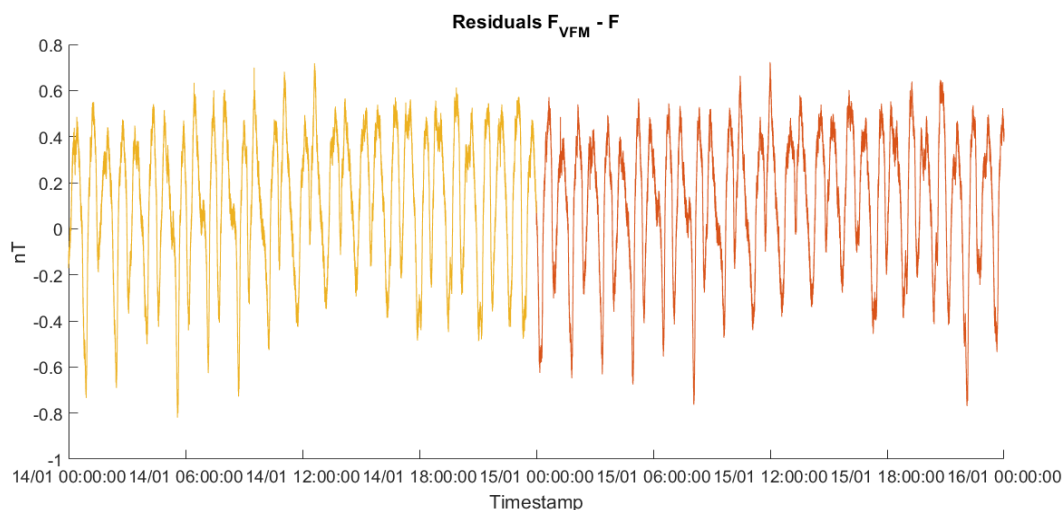


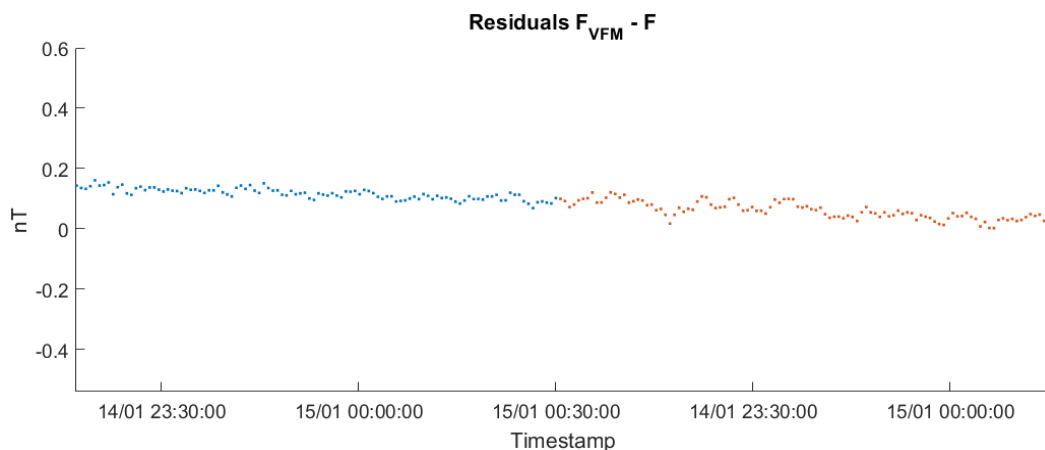
Figure 3-25: Plot of standard deviation of B components in VFM frames.

#### 4. ON-DEMAND analysis

An update of the CCDB AUXxVFM\_C\_ file of Swarm Alpha have been deployed in operations on 17/01/2017. The first data produced using the new CCDB relates to day 15/01/2017. After this update no discontinuities or other strange effects have been detected on the residuals, as you can see from the figures below.



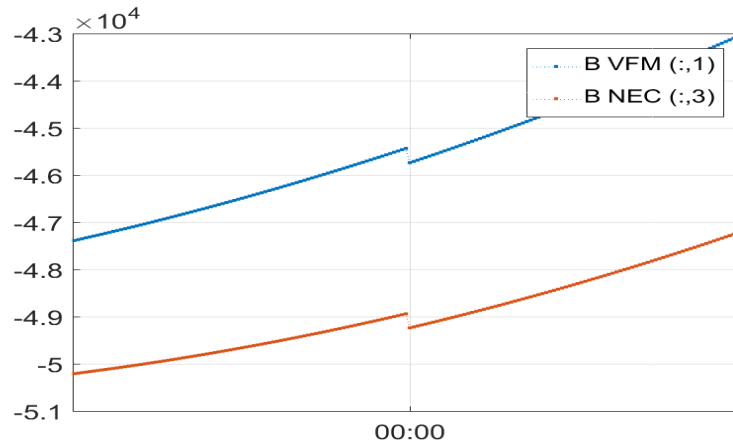
**Figure 4-26:** Plot of standard deviation of B components in VFM frames. of residual of  $F_{VFM} - F$  for S/C A covering 14<sup>th</sup> and 15<sup>th</sup> of January.



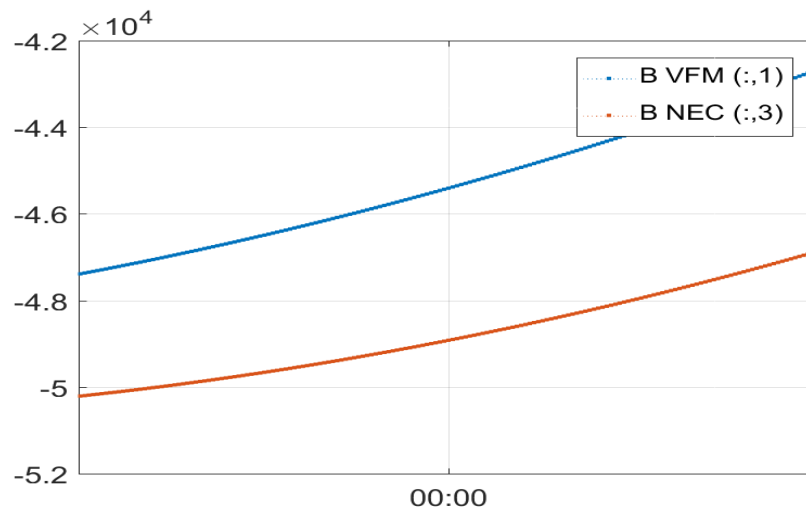
**Figure 4-27:** Plot of standard deviation of B components in VFM frames. of residual of  $F_{VFM} - F$  for S/C A (zoomed for daybreak 14/01 – 15/01)

On 17/01/2017 we have deployed in operations also an updated version of the CCDB AUXxVFM\_C\_ file of Swarm Charlie. We have analysed the trend of the vector data from Swarm Charlie (VFM and NEC frame) for the days 14 and 15 Jan.2017 as can be seen in the Figure 28. One unexpected discontinuity ( $\sim 300$  nT) seems to be introduced between the end of day 14 and beginning of the day 15 on the X (VFM) and Z (NEC) components.

A more updated version of this CCDB have been tested and therefore deployed in operations (i.e., 19/01/2019). The trend of the vector data of Swarm Charlie after the introduction of the new CCDB is shown in Figure 29. This new CCDB do not produce any discontinuity.



**Figure 28:** Trend of X component in VFM frame and Z component in NEC frame (zoomed for daybreak 14/01 – 15/01) of Swarm Charlie.



**Figure 29:** Trend of X component in VFM frame and Z component in NEC frame (zoomed for daybreak 14/01 – 15/01) of Swarm Charlie.

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