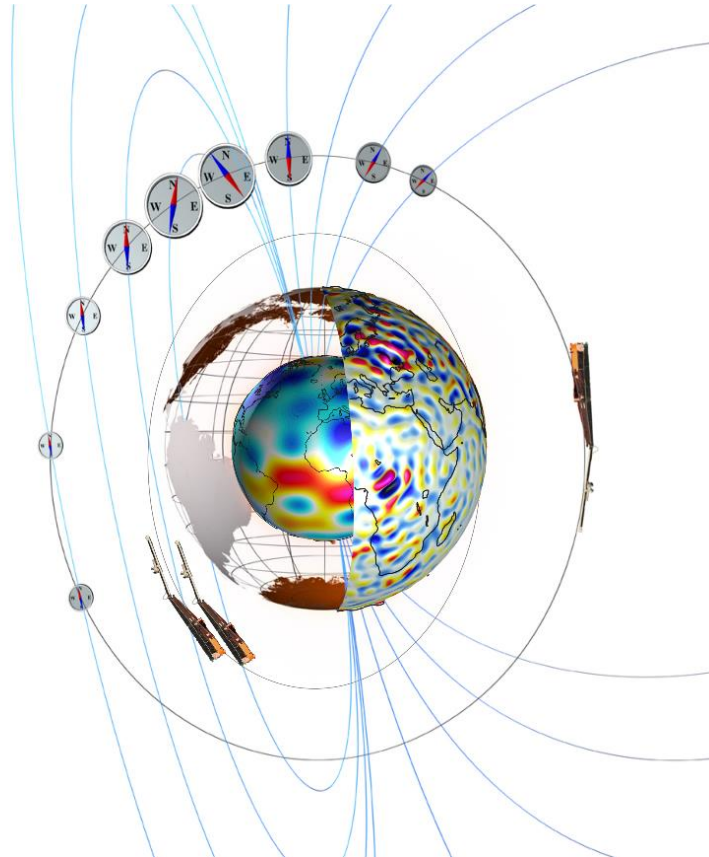


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# Swarm DISC Weekly Report 2017/20: 2017/05/15 - 2017/05/21

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**Abstract** : This is the **Swarm Data Innovation and Science Cluster** (Swarm DISC) Weekly report on Swarm products quality, covering the period from 15 May to 21 May 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	21 Jun 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 2.2.

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 3.18p2, L2-Cat2 1.16p1.
- 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 (17/01/2017), S/C B – CCDB 0014 (17/03/2017), S/C C – CCDB 0014 (19/01/2017), ADF 0101
- MPPF-CVQ v.03.03

### 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-SRCO-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

[RD.20] Swarm Weekly Operations Report #182, SW-RP-ESC-FS-6278

[RD.21] SW-RP-SER-GS-010\_SPPA\_SwarmWeeklyReport\_201716\_20170417\_20170423\_1.1.pdf



## 2. Summary of the observations

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

A collision avoidance manoeuvre was successfully performed on Swarm Bravo on 16 May 2017 at 00:14:27 UTC for a duration of 95 seconds, equivalent to 2 cm/s. No slew manoeuvre was required and EFI was in stand-by at the time of the manoeuvre.

### 2.2 Plan for operational processor updates

**L1BOP:** In the next delivery of the L1BOP v03.19 (delivery date TBD), 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.
- Update of vector data calibration and disturbance characterization.
- Separation of pre-flight from the in-flight VFM calibration parameters.

The following activities are on-going on PLASMA processor:

- Cross-verification on-going: hopefully a fully cross-verified PLASMA processor will be included in the next delivery.
- Modification on the computation of the Te by using mainly the high gain probe.
- The separation of LP data from TII data
- Two LP products will be produced: one at LP timestamp and the other one interpolated at exact UTC

On ACCELE processor: a new L1B ACC product containing a subset of parameters of the current ACCx\_PR\_1B will be produced.

**L2 Cat-2:** In the next delivery of the L2 Cat-2 OP v1.17 (delivery date TBD) 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
- Improvement of L2 Cat-2 CDF global attributes

## 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:
  - ASM-V data: IPGP/LETI will deliver an updated version of the ASM vector data that will be available for all the users.
  - Delivery of the LP Sweep mode dataset for all S/C from 02/12/2013 to 31/03/2017 to be distributed to Mission users only.
  - IRF will deliver an updated 16 Hz Faceplate dataset to be distributed to all users (delivery date TBD).

## 2.4 Summary of observations for 2017, Week 20 (15/05 - 21/05)

During the monitored week no events have been found and investigated.

## 3. Routine Quality control

### 3.1 Gaps analysis

- 1 second data gaps in MAGA\_LR\_1B, MAGA\_CA\_1B, MAGA\_HR\_1B products caused by re-occurrences of GPSR data lost anomaly as reported in [RD.21]:
  - S/C A: 19/0/52017 at 10:17:47
  - S/C A: 20/05/2017 at 13:33:31
  - S/C A: 21/05/2017 at 17:36:44
- 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 20: 15/05 - 21/05.

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

The relevant parameters that have been monitored are:

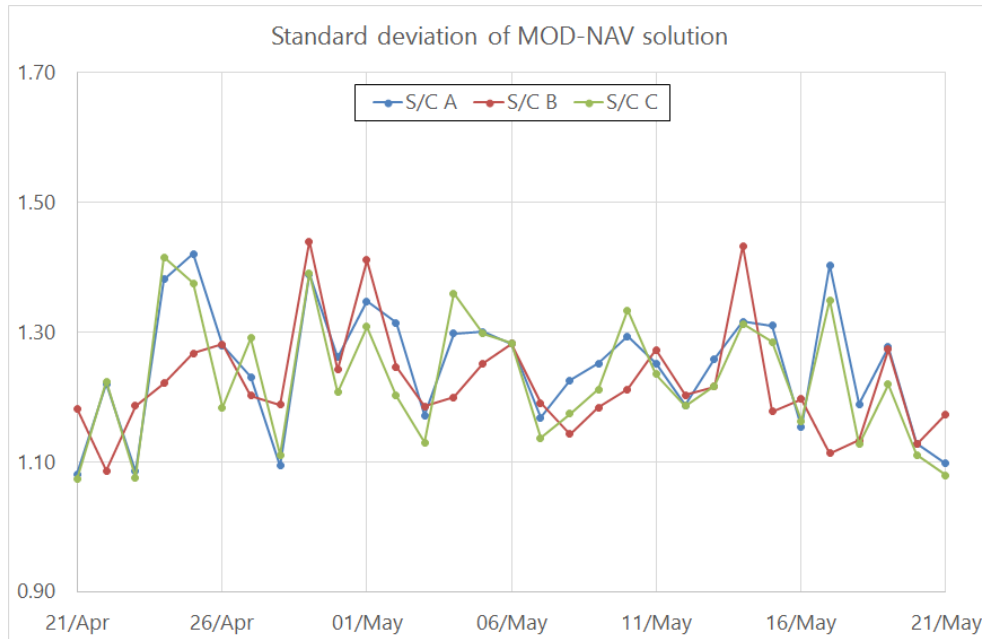
- Position difference between calculated Medium Accuracy orbits (**MODx\_SC\_1B**) and on-board solution (**GPSxNAV\_0**). Threshold values for such differences have not been assessed yet: we have just monitored the average values and maximum variations around the week. They are reported in tables in 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:
  - The **average difference** on a given day exceeds the position accuracy requirement for the mission (1.5 m),
  - 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).
  - 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

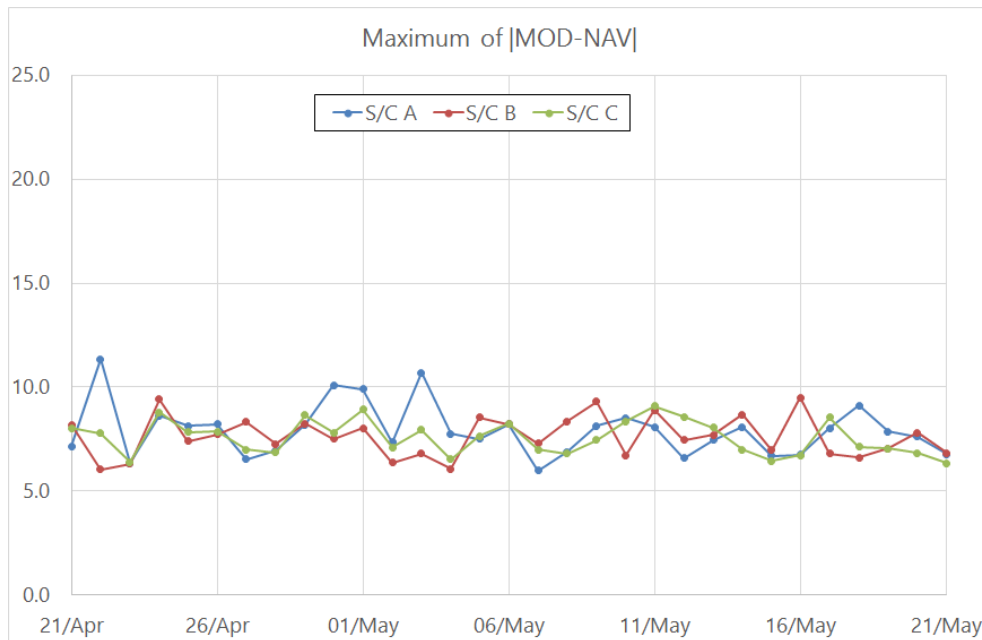
In Table 3-2, one can see the statistics of the differences between MOD and on-board solution positions for S/C A, B and C respectively. In the third column the maximum differences (maximum negative and maximum positive) are reported. The standard deviation is in the fourth column. Maxima, minima and 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, 15/05 - 21/05, Position difference					
Day	Average difference (m)	Maximum difference (m)		Standard deviation (m)	Notes
15/05	0.08	-6.7	6.4	1.31	
16/05	0.11	-6.3	6.8	1.15	
17/05	0.12	-7.3	8	1.4	
18/05	0.07	-9.1	7.2	1.19	
19/05	0.11	-7.9	6.4	1.28	
20/05	0.07	-6	7.6	1.13	
21/05	0.07	-5.9	6.8	1.1	
Swarm B, 15/05 - 21/05, Position difference					
Day	Average difference (m)	Maximum difference (m)		Standard deviation (m)	Notes
15/05	0.09	-7	6.7 (Y)	1.18	
16/05	0.05	-6.6	9.5 (X)	1.2	
17/05	0.09	-6	6.8	1.11	
18/05	0.2	-6.6 (Y)	5.6	1.13	
19/05	0.1	-7.1	7 (Y)	1.27	
20/05	0.17	-7.3	7.8 (X)	1.13	
21/05	0.14	-5.9 (Y)	6.8	1.17	
Swarm C, 15/05 - 21/05, Position difference					
Day	Average difference (m)	Maximum difference (m)		Standard deviation (m)	Notes
15/05	0.06	-6.5	6.1	1.29	
16/05	0.13	-6.7	6.3	1.16	
17/05	0.17	-7.9	8.5	1.35	
18/05	0.08	-7.1	6	1.13	
19/05	0.13	-7	7	1.22	
20/05	0.03	-6.8 (Y)	6.5	1.11	
21/05	0.11	-6.3	6.3	1.08	



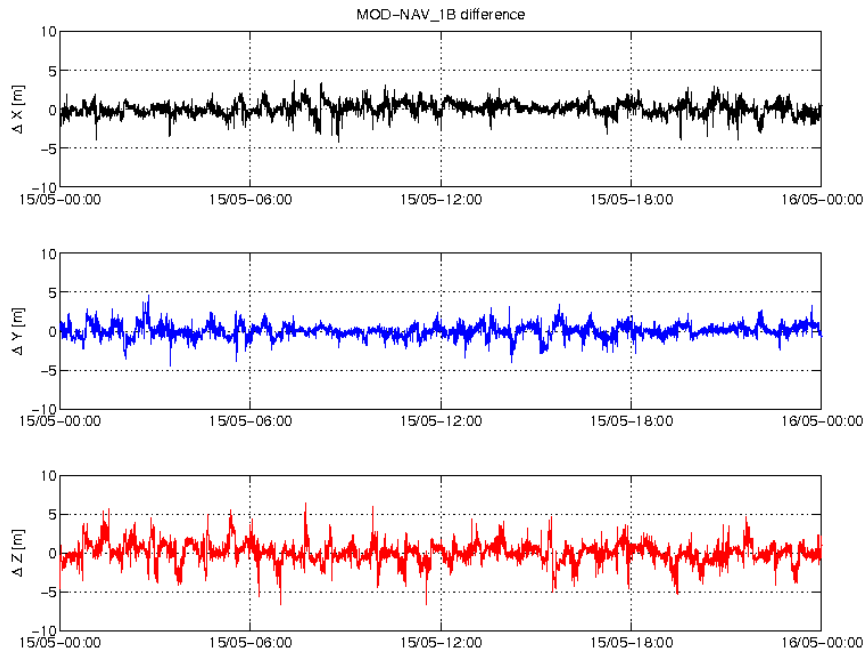
**Figure 3-1:** Plot of the standard deviation of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.



**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 (15/05, 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].

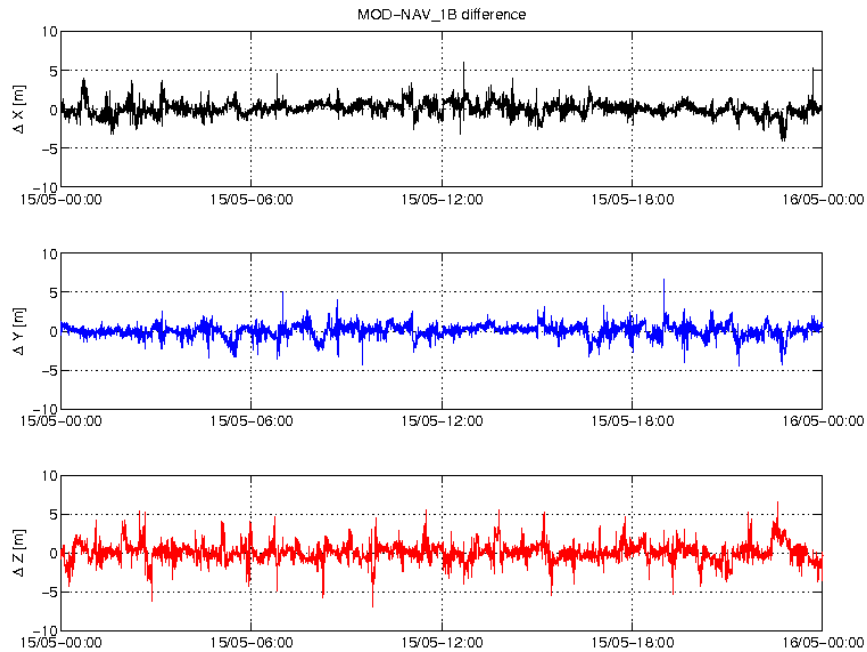


**Figure 3-3:** Difference MOD-GPSNAV, S/C A, 15/05. From top to bottom: X, Y and Z-axis



### 3.2.1.2 Swarm B

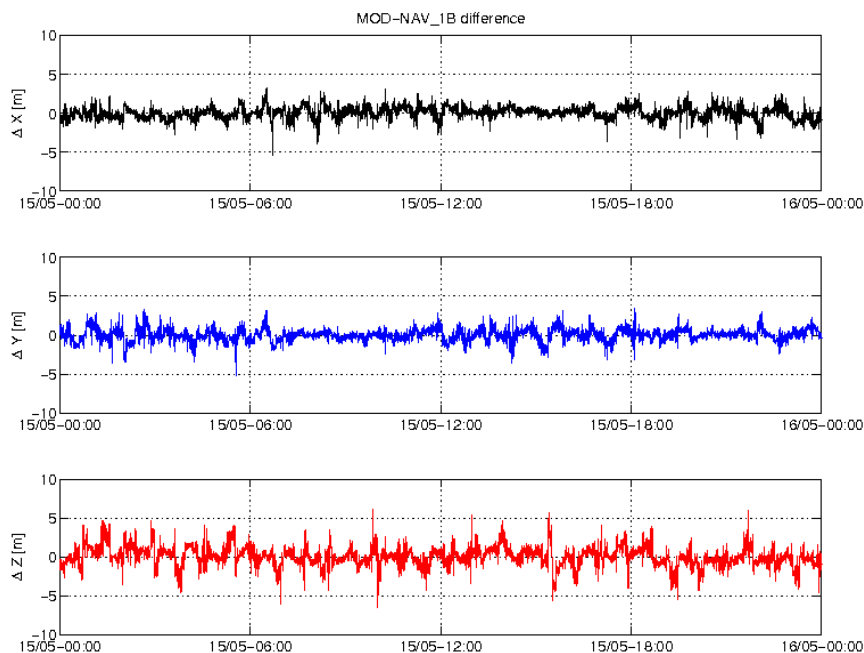
Below is presented plot of MOD-NAV differences for S/C B, taken at the beginning of the week (15/05, Figure 3-4). From top to bottom, the plots show of MOD-NAV differences in ITFR reference frame: on X, Y and Z-axis respectively, differences are given in [m].



**Figure 3-4:** Difference MOD-GPSNAV, S/C B, 15/05. 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 (15/05, Figure 3-5). From top to bottom, the plots show of MOD-NAV differences in ITRF reference frame: on X, Y and Z-axis respectively, differences are given in [m].



**Figure 3-5:** Difference MOD-GPSNAV, S/C C, 15/05. 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

Collision avoidance manoeuvre was executed successfully on 16/05/2017. Details available in Weekly Operations Report [RD.20].

### 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  $\pm 60000$  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  $\pm 1$  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 20: 15/05 - 21/05.

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 – violation of:
  - VFM-ASM residuals threshold on 16/05, 17/05, 18/05, 21/05;
  - mean value of residuals threshold on 15/05, 16/05, 17/05, 18/05, 19/05, 20/05;
- S/C B – violation of:
  - VFM-ASM residuals threshold on 15/05, 16/05, 17/05, 18/05, 19/05, 20/05, 21/05;
  - standard deviation of residuals threshold on 15/05, 20/05, 21/05.

#### 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.

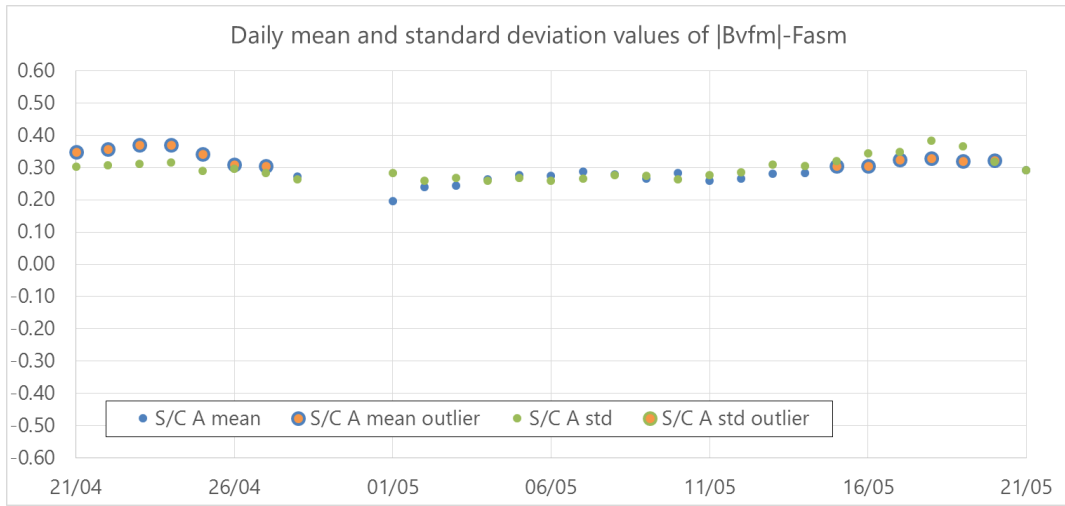
The ASM-VFM difference is defined as follow:

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

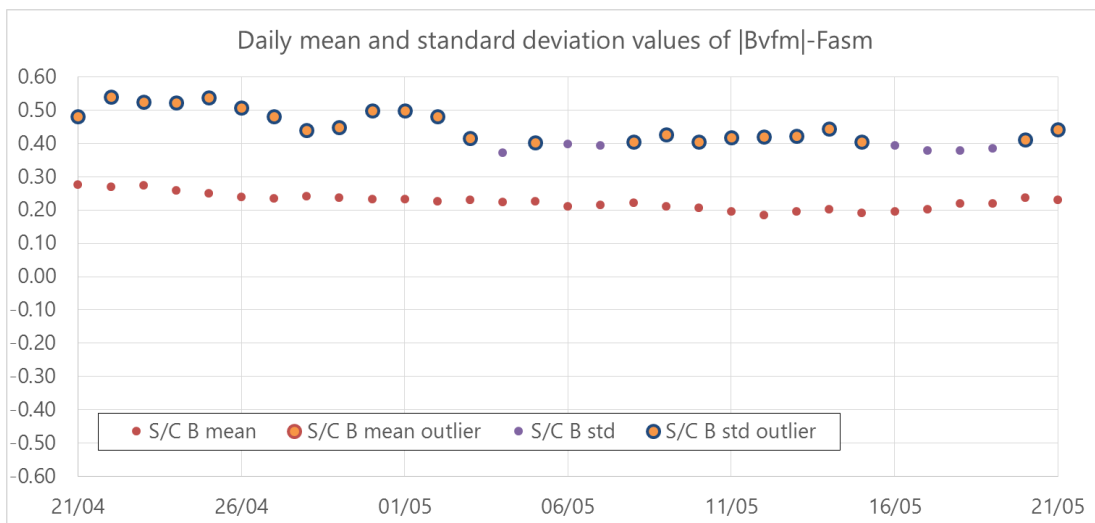
Figure 3-6 and Figure 3-7 show the daily mean (circles) and standard deviation (crosses) of dF of the last month for Swarm A and Swarm B respectively.

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

Swarm A, 15/05 - 21/05, ASM-VFM difference					
Day	Max (nT)	Min (nT)	Standard deviation (nT)	Mean (nT)	Notes
15/05	0.87	-0.94	0.32	<b>0.304</b>	
16/05	0.87	<b>-1.02</b>	0.34	<b>0.305</b>	
17/05	0.9	<b>-1.05</b>	0.35	<b>0.326</b>	
18/05	0.91	<b>-1.04</b>	0.38	<b>0.329</b>	
19/05	0.91	-0.94	0.37	<b>0.321</b>	
20/05	0.96	-0.79	0.32	<b>0.322</b>	
21/05	<b>1.09</b>	-0.66	0.29	0.293	
Swarm B, 15/05 - 21/05, ASM-VFM difference					
Day	Max (nT)	Min (nT)	Standard deviation (nT)	Mean (nT)	Notes
15/05	<b>1.22</b>	-0.98	<b>0.41</b>	0.191	
16/05	<b>1.24</b>	-0.89	0.39	0.196	
17/05	<b>1.2</b>	-0.85	0.38	0.202	
18/05	<b>1.15</b>	-0.89	0.38	0.22	
19/05	<b>1.09</b>	-0.89	0.38	0.221	
20/05	<b>1.14</b>	<b>-1.01</b>	<b>0.41</b>	0.237	
21/05	<b>1.13</b>	<b>-1.07</b>	<b>0.44</b>	0.231	



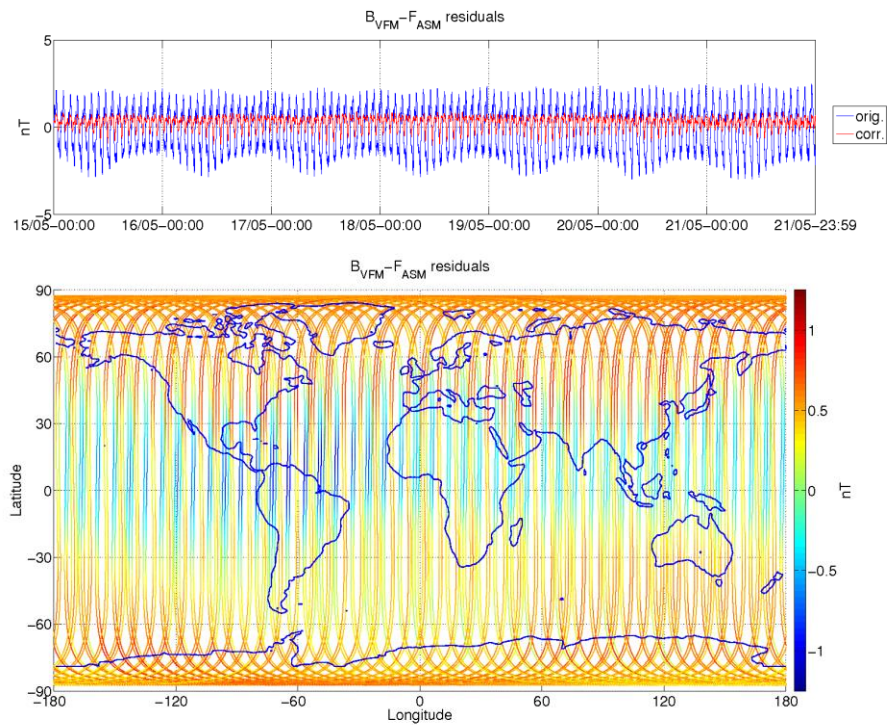
**Figure 3-6:** Daily mean and standard deviation values of ASM-VFM residuals (defined as  $dF = |B_{VFM}| - F_{ASM}$ ) for S/C A.



**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

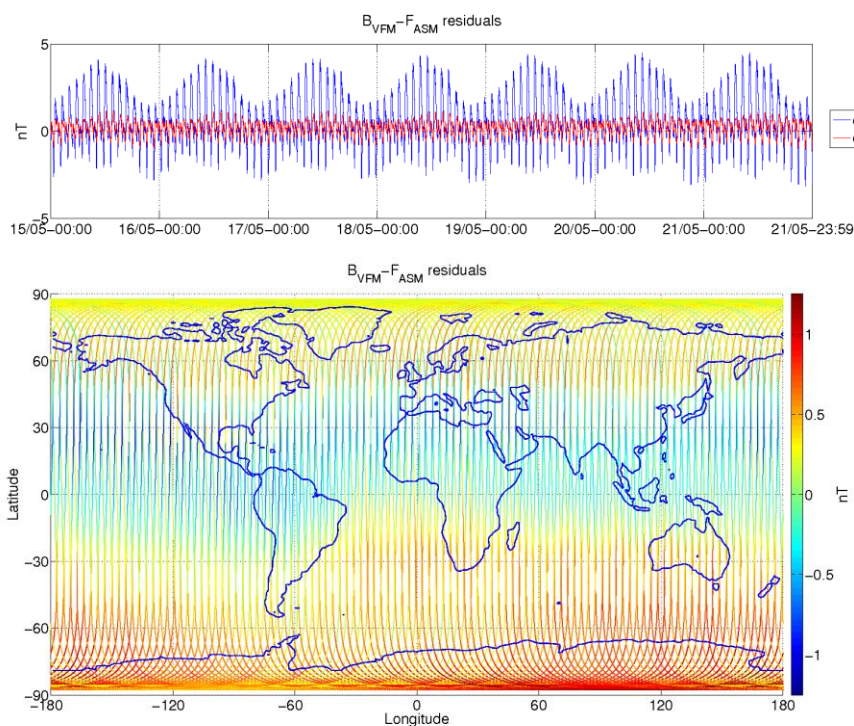
The daily peak-to-peak difference around the week stays within  $[-1.05 - 1.09]$  nT. Below follow two plots of such differences for current week (Figure 3-8).



**Figure 3-8:** ASM-VFM residuals for S/C A, during monitoring period 15/05-21/05. 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  $[-1.07 - 1.24]$  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 15/05-21/05. 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  $T_{EU}$ .

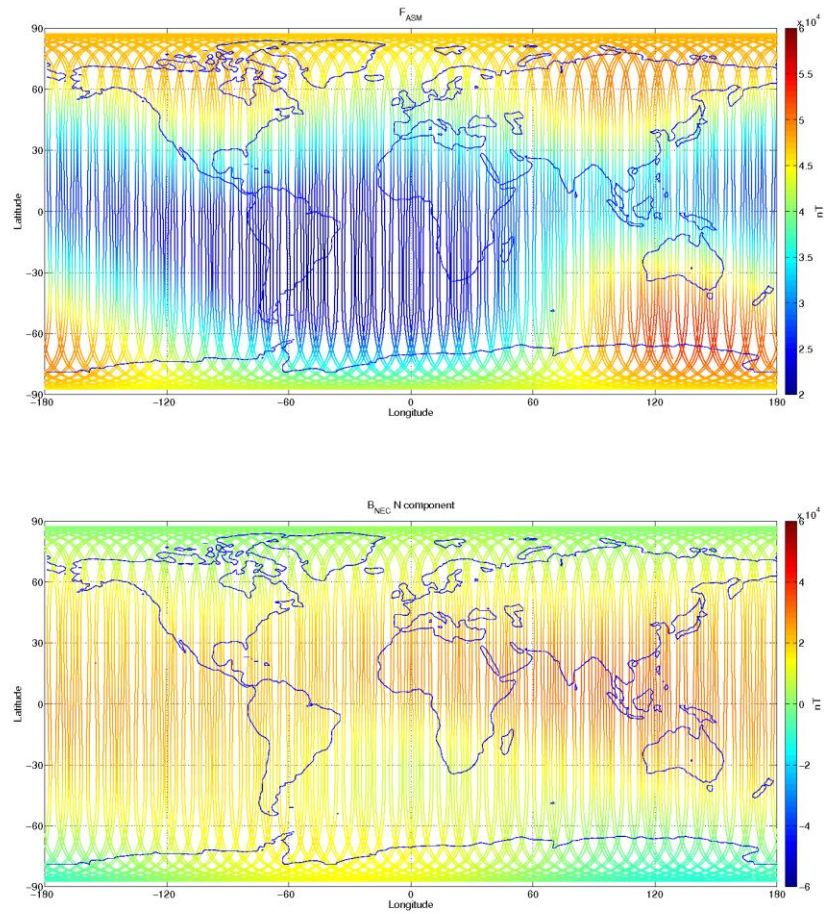
For S/C A, B and C, for reported period, the temperatures behaved as expected.



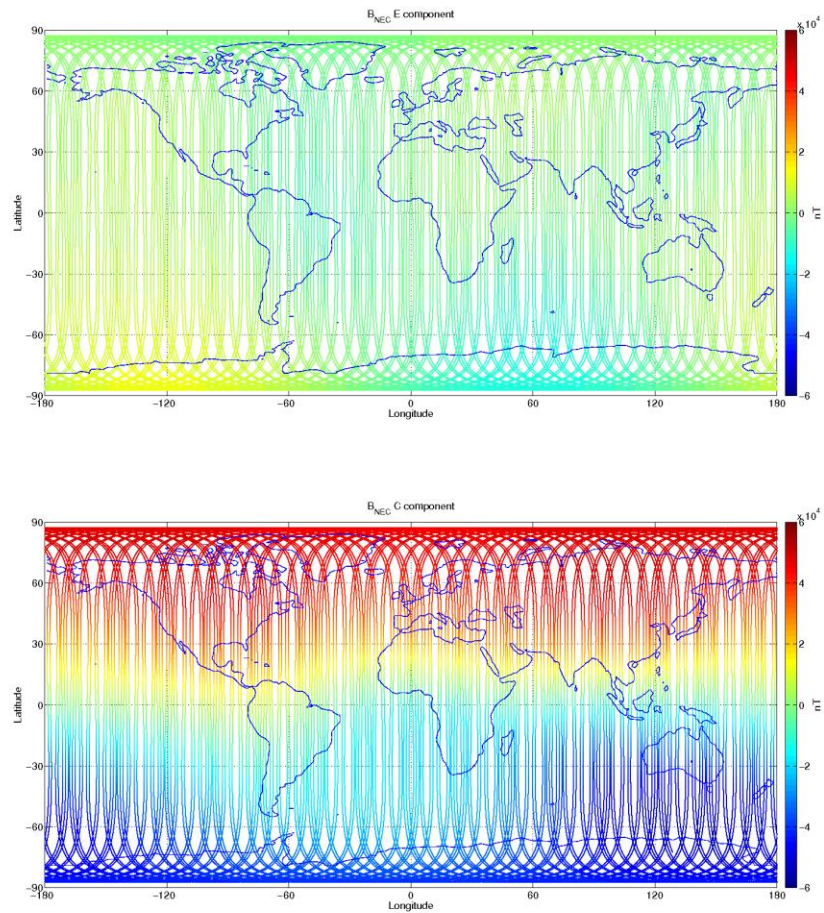
### 3.3.4 Magnetic time series visual inspection

#### 3.3.4.1 Swarm A

Map plots of magnetic field measurement for week 20 for S/C A can be seen in Figure 3-10 below.



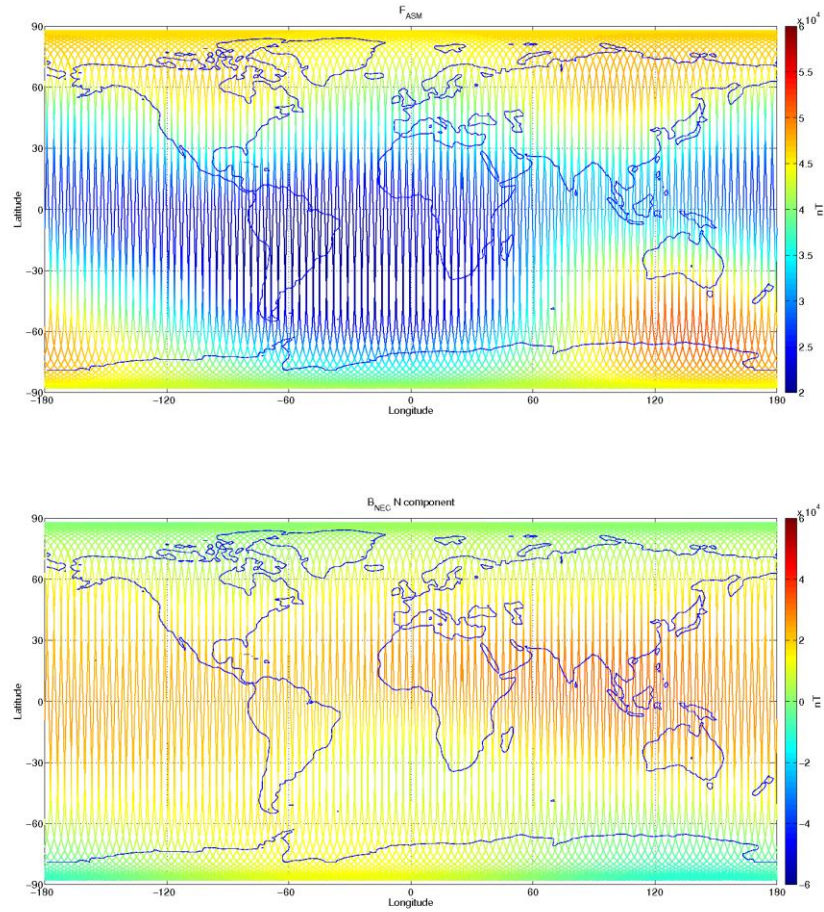


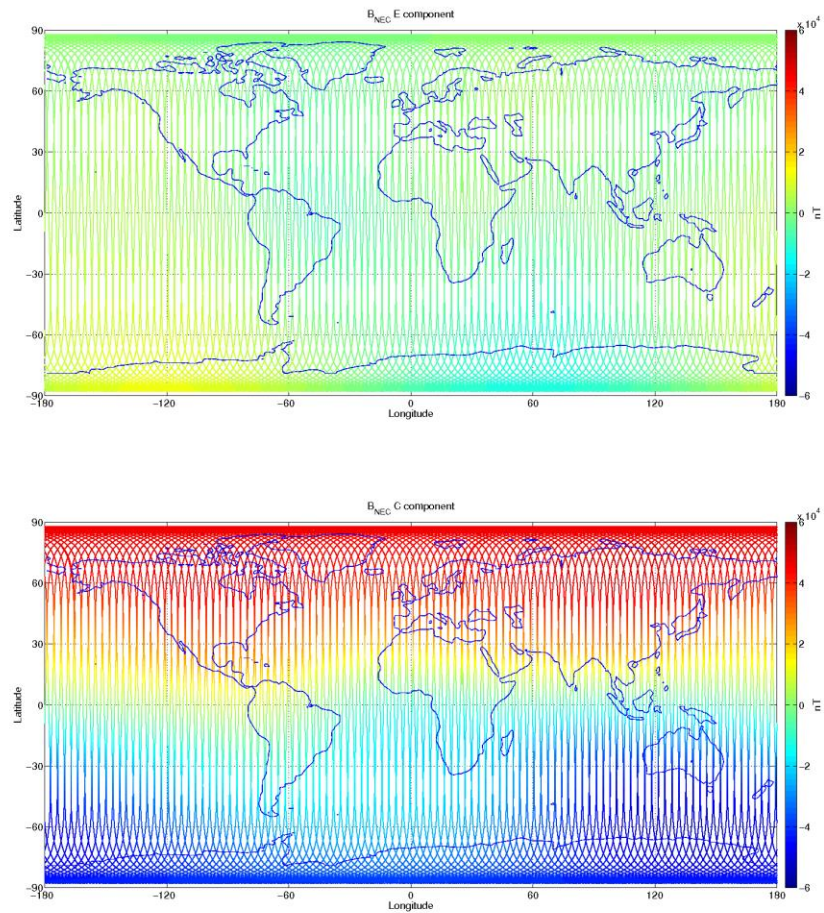


**Figure 3-10:** S/C A, world map plots of the geomagnetic field and components measured during monitoring period 15/05-21/05. From top to bottom: F-magnetic field from ASM measurement,  $B_{NEC}$  components (North, East, and Centre) of magnetic field from VFM measurement.

### 3.3.4.2 Swarm B

Map plots of magnetic field measurement for week 20 for S/C B can be seen in Figure 3-11 below.



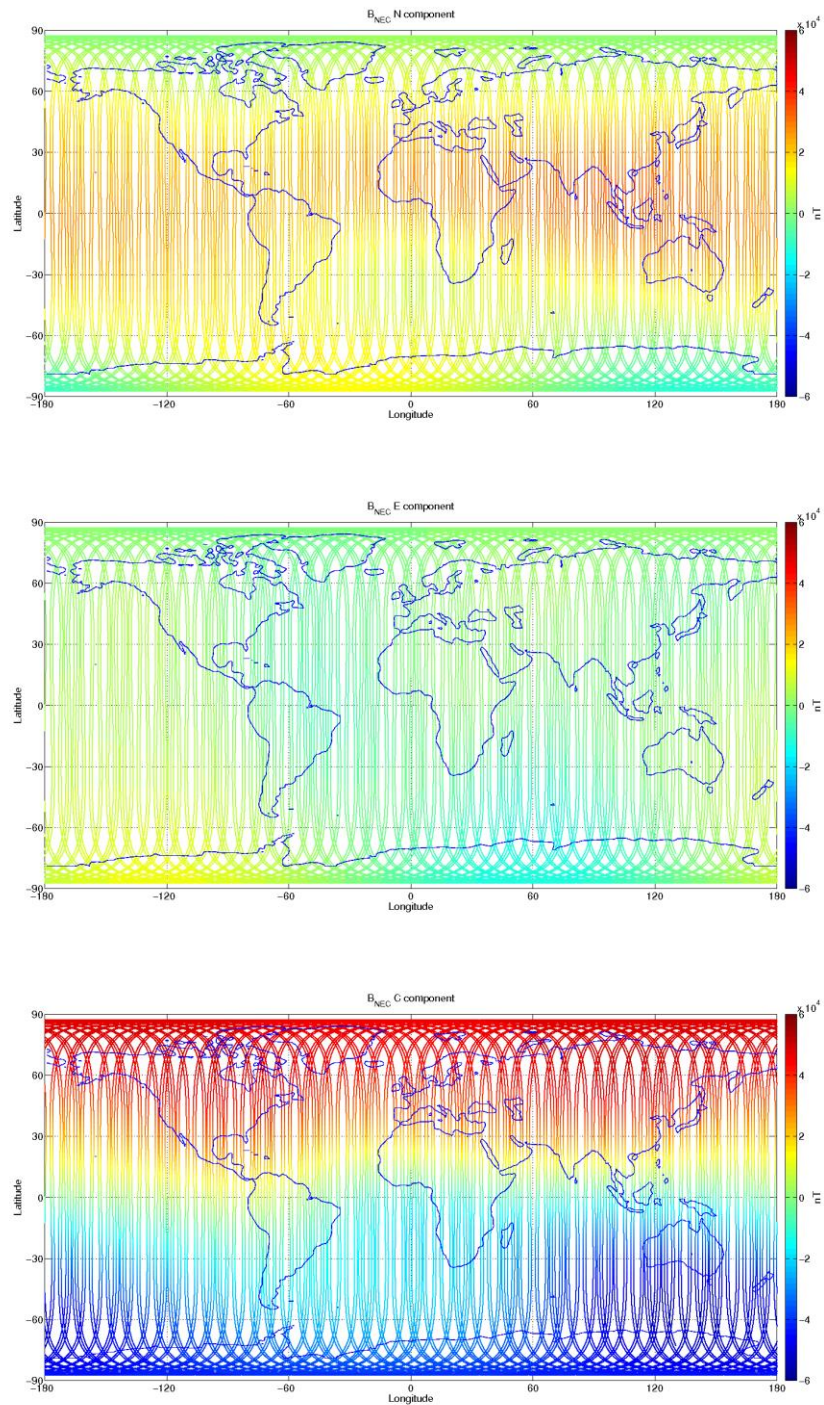


**Figure 3-11:** S/C B, world map plots of the geomagnetic field and components measured during monitoring period 15/05-21/05. From top to bottom: F-magnetic field from ASM measurement,  $B_{NEC}$  components (North, East, and Centre) of magnetic field from VFM measurement.



### 3.3.4.3 Swarm C

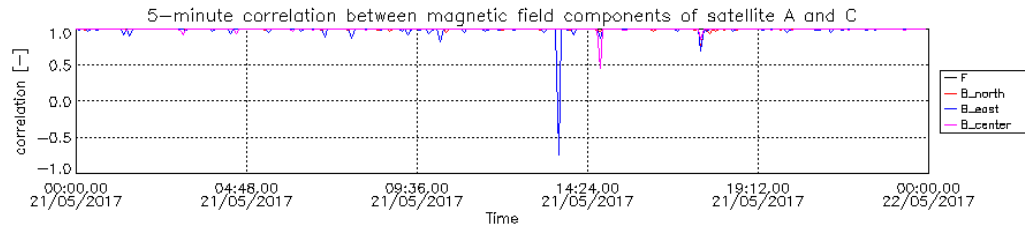
Map plots of magnetic field measurement for week 20 for S/C C can be seen in Figure 3-12.



**Figure 3-12:** S/C C, world map plots of the geomagnetic field and components measured during monitoring period 15/05-21/05. 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

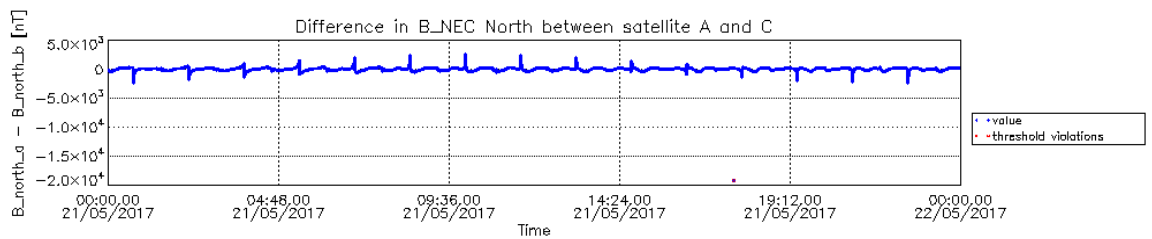
In the plot below is shown the correlation in 5-minutes intervals of magnetic data between satellite A and C. B\_north, B\_east, and B\_center are the components of the magnetic field vector in NEC frame.



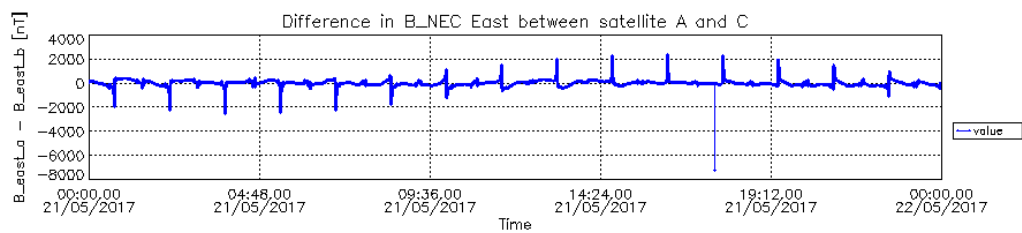
**Figure 3-13:** Correlation in magnetic data between satellite A and C for B\_north, B\_east, and B\_center components of  $B_{NEC}$  are the components of the magnetic field vector in NEC frame

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

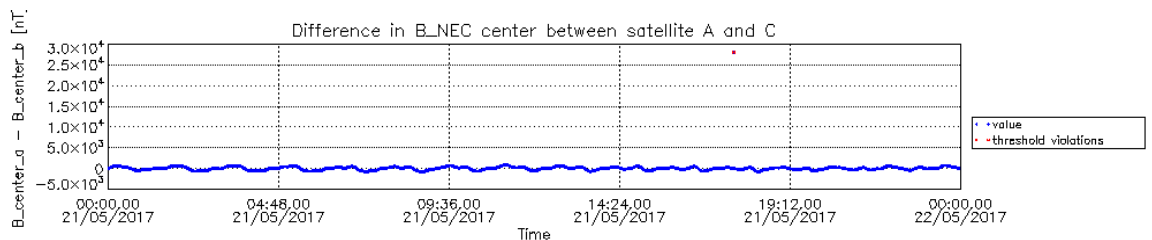
The next three plots show the differences in magnetic data between satellite A and C. Threshold is set to 8 000 nT for each component.



**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.

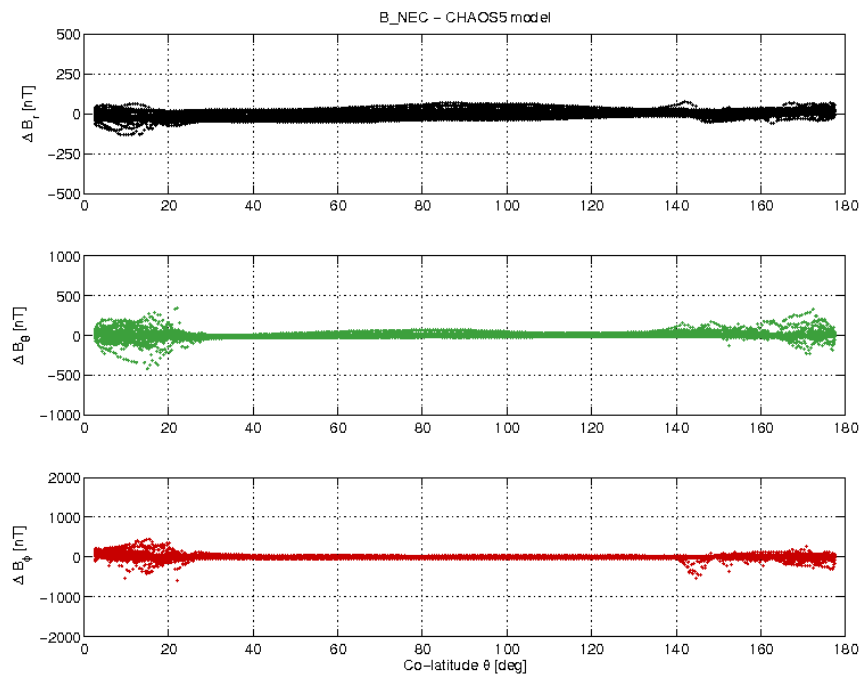
Figure 3-17, Figure 3-19 and Figure 3-21 show field residuals  $\Delta B = B_{NEC} - B_{Chaos5}$  (all versus co-latitude in degrees), from top to bottom: 1)  $B_r$ , 2)  $B_\theta$  and 3)  $B_\phi$ .

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 15/05 of: (1-2-3) residuals of  $B_{NEC} - B_{Chaos5}$  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 15/05  $B_{NEC} - B_{Chaos5}$  vs colatitude.

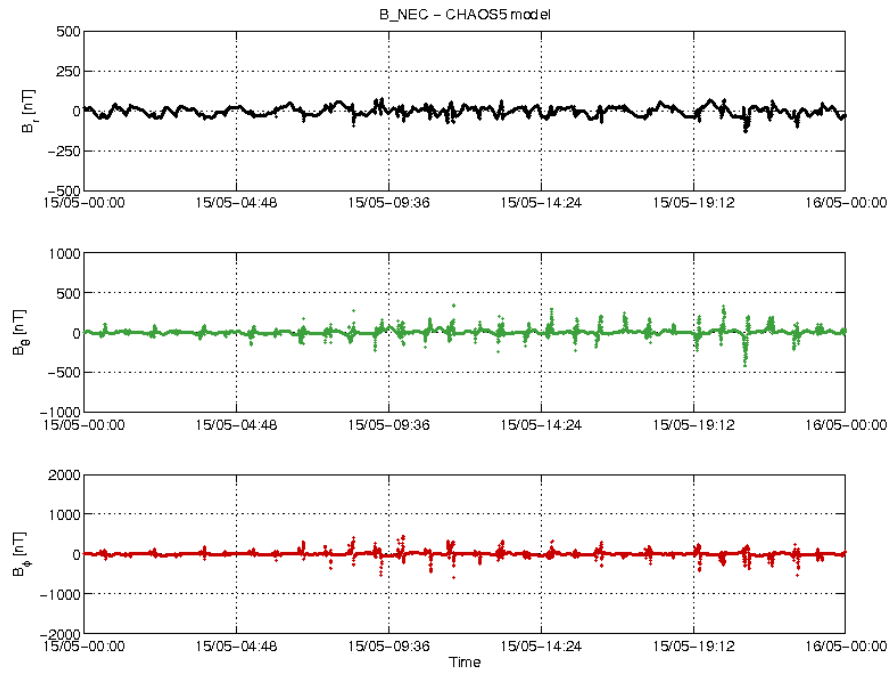


Figure 3-18: S/C A day 15/05: time series of  $B_{NEC} - B_{Chaos}$  residuals.

### 3.3.7.2 Swarm B

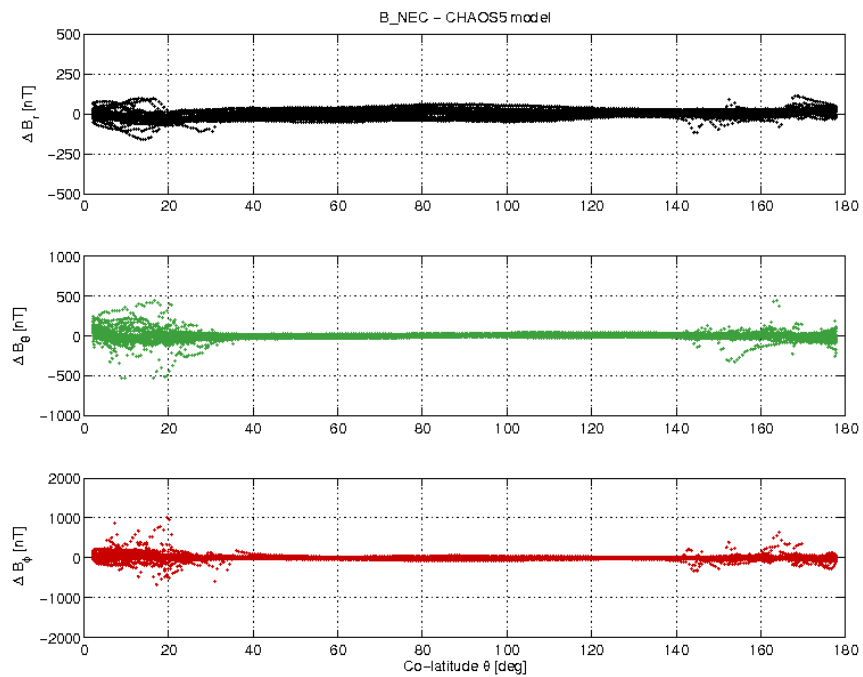


Figure 3-19: S/C B day 15/05  $B_{NEC} - B_{Chaos}$  difference vs colatitude.

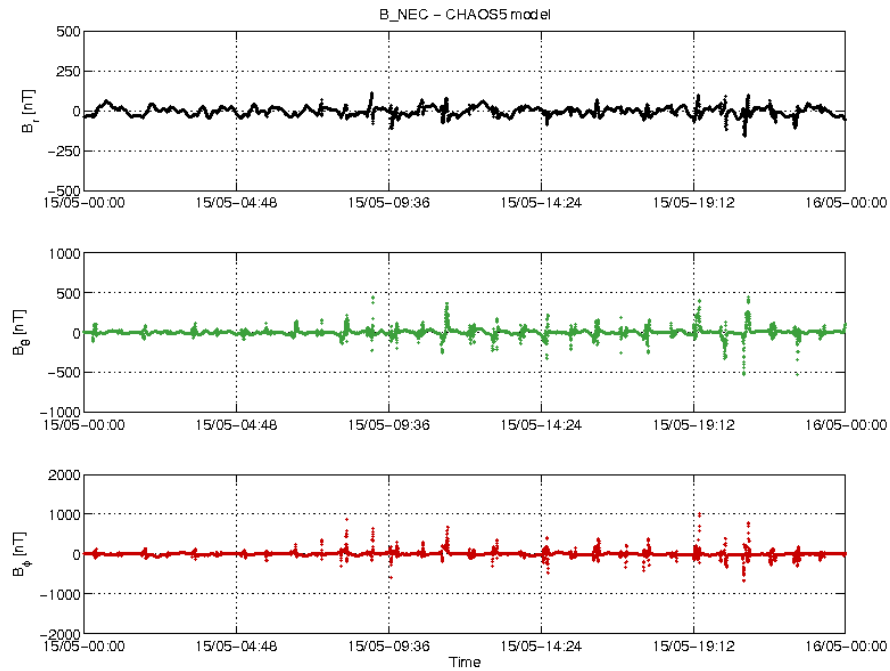


Figure 3-20: S/C B day 15/05 time series of  $B_{NEC} - B_{Chaos}$  residuals.

### 3.3.7.3 Swarm C

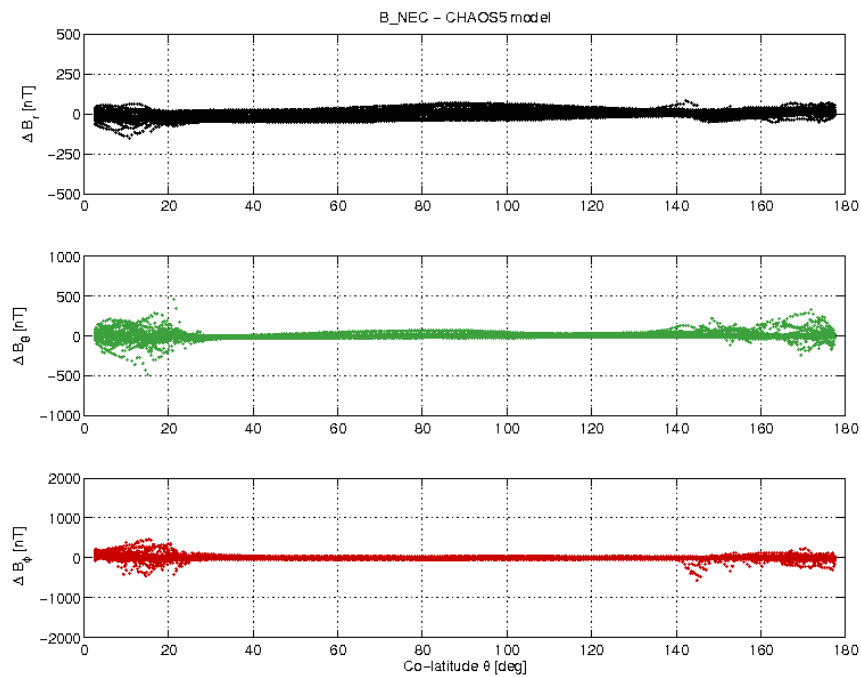
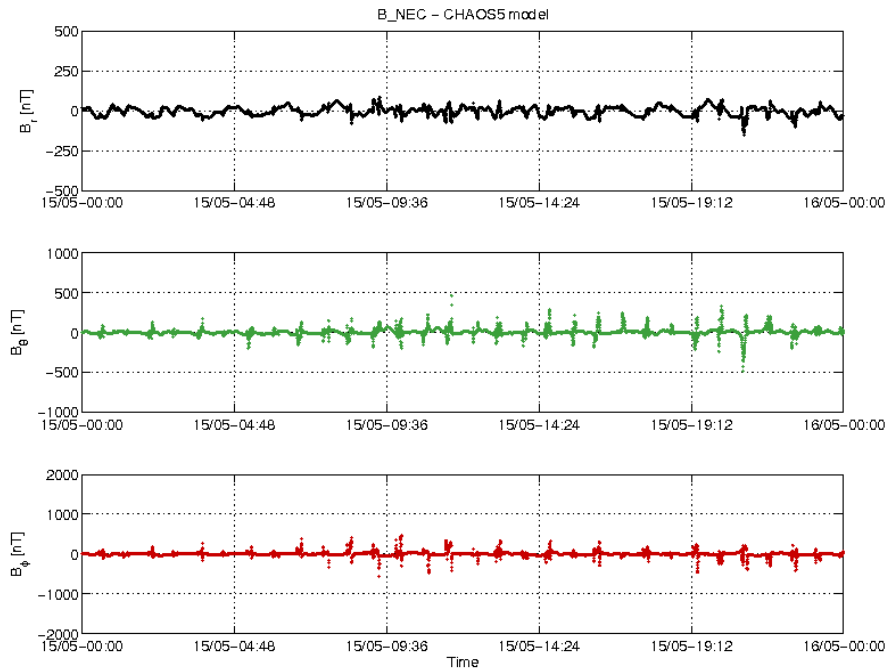


Figure 3-21: S/C C day 15/05  $B_{NEC} - B_{Chaos}$  difference vs colatitude.



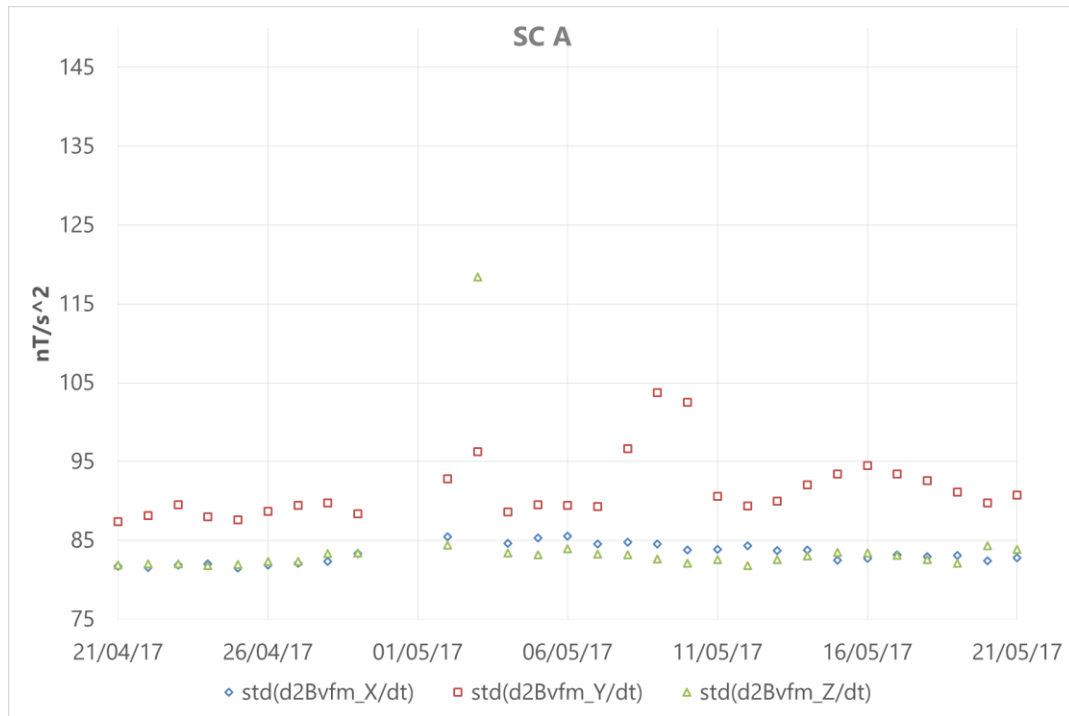


**Figure 3-22:** S/C C day 15/05 time series of  $B_{NEC} - B_{Chaos}$  residuals.

### 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.

The spike we observe on 03/05/2017 on the plot is caused by the bug in script that occurs when there is gap in data used to calculate standard deviation

3.3.8.2 Swarm B

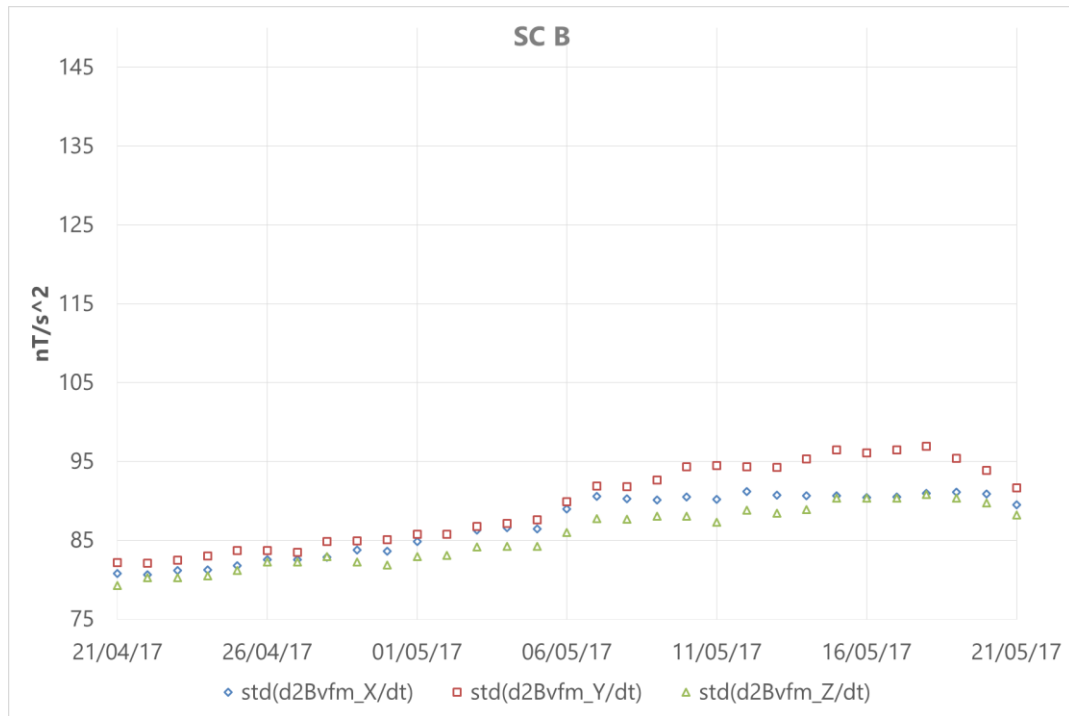


Figure 3-24: Plot of standard deviation of B components in VFM frames.

3.3.8.3 Swarm C

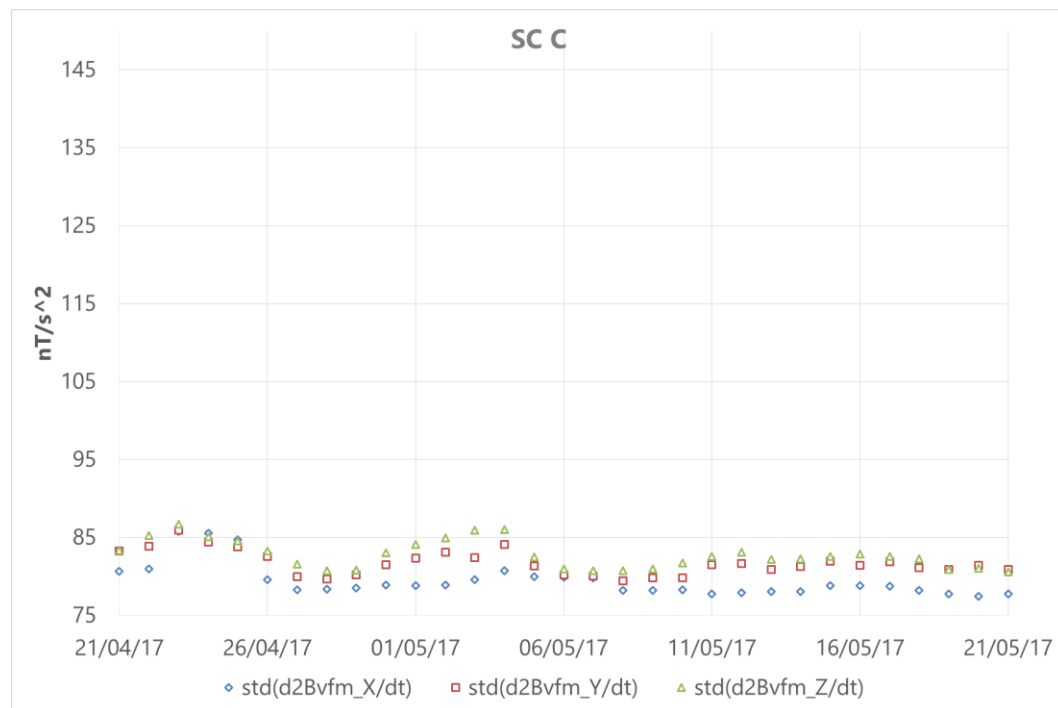


Figure 3-25: Plot of standard deviation of B components in VFM frames.

## 4. ON-DEMAND analysis

Nothing to report.

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