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IDEAS+ Swarm Weekly Report 2016/17: 2016/04/25 - 2016/05/01

Abstract : This is the **Instrument Data Quality Evaluation and Analysis Service Plus** (IDEAS+) Swarm Weekly report on Swarm products quality, covering the period from 25 April to 01 May 2016.

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TABLE OF CONTENTS

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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	10 May 2016	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 ADF 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 IDEAS+ Swarm 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 PDGS, FOS, Mission Management, Post-Launch Support Office, Expert Support Laboratories, Quality Working Groups, 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: IDEAS+ action and ticketing system (http://requests-sppa.serco.it/RT3/index.html).

2. If triggered by IDEAS+ Swarm 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), **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.p5.

- 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 0010 (14/04/2016), S/C B – CCDB 0011 (14/04/2016), S/C C – CCDB 0010 (14/04/2016), 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-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

[RD.19] SW-RP-ESC-FS-6222_Swarm_Weekly_Operations_Report#127_25-04-2016_01-05-2016.pdf

2. SUMMARY OF THE OBSERVATIONS

2.1 General status of Swarm instruments and Level 1B products quality

TII Image anomaly update: several tests have been performed in the past months, especially on Swarm Charlie. An important achievement from March 2016 was that the so called "ring feature" is in fact originating from incoming ions impacting the inner dome of the sensors: a "blind" sensor test has been performed closing the shutter and maintaining the MCP and Phosphor voltages on, verifying that, in such conditions, no ring appeared in the images. A long run of continuous and semi-continuous operations in different conditions has also been done, and this evidenced the ring feature appearing and growing after few orbits in active state, falling abruptly when going back to 1 orbit/day operations. Curiously, the V sensor seems to be less affected than the H sensor.
A discussion is on-going on the opportunity to heat the sensors up in order to expel contaminants as much as possible. This can be done either through a yaw manoeuvre pointing to the Sun for several orbits/steps (very risky) or switching on the heaters located underneath the electronics box (less risky but the effectiveness should be evaluated).

VFM anomaly on Swarm Bravo: On April 29, FOS reported about an anomaly in the VFM telemetry of Swarm Bravo, occurring since April 26 but not discovered until 29. The issue is, in fact, very subtle [e-mail from G. Albini, 29/04/16]:

"we are experiencing since DoY 117 (26/04) a strange behaviour in the HK and science data of the VFM-A unit on SW-B satellite. We did not get any anomalous on board event or parameter out of limit, but, starting the 26/04 at 21:39 UTC we can see the following:
the HK packets are generated either with a frequency higher than 1/60 seconds or with gaps (even one gap of minutes): note that the gap is not seen at source sequence counter level, but the generation frequency is not consistent (when the packets are generated the frequency looks ok, but we see times where no packets are generated, and then the
generation resumes with the following source sequence counter); the frequency of the Science packet with APID 646 (VFM_AvgFieldTm) appears to behave the same as above; It looks like a data buffering issue at instrument level."

After a power cycle of the instrument, done on 29/4, the issue disappeared, but this caused the failure of the Level 1B processor (MAGNET segment) for 4 days in a row (26 to 29/4), because the timestamps are badly ordered and it is impossible to sort the time correctly with the current set up. GMV has already prepared a fix, which worked also for the anomaly of February on Charlie (SEU on VFM), which makes at least the processor complete the production, even though further investigations are needed in order to understand if it is possible to recover data in terms of quality. The fix will be delivered not earlier than Sept./Oct., so that the production could not be recovered before that time. We at putting in place dedicated daily checks on the Level 0 completeness and consistency in order to avoid such kind of situations in the future.

2.2 Plan for operational processor updates

L1BOP: In the next delivery of the L1BOP after the PDGS evolution activities (not earlier than Sept./Oct. 2016) the following changes will be implemented into the MAGNET processor:

- 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

- 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.

For what concern the ORBATT processor, two changes to be implemented are under discussion:

- A STR Inter-Boresight Angles correction model

- An increase of the frequency of the STR L0 product from 1 Hz to 2 Hz

L2 Cat-2: the L2 Cat-2 OP v01.15 patch 5 that impacts the computation of the FAC-combined uncertainties has been deployed in operations on 03 May 2016.

Any other delivery of the L2 Cat-2 OP is postponed after the PDGS evolution activity (April – July 2016).

2.3 Quality Working Group and Cal/Val Coordination

The former "Task Force" deputed to study the ASM-VFM residuals, has been reshaped in a Magnetic Measurements Expert Group (MMEG). The first MMEG meeting was held in Warsaw (GMV premises) on **10-11/03/2016.** During this meeting the following decisions have been taken:

ASM-VFM Scalar Residual:

- VFM calibration issue:
  - Finalize the covariance analysis between parameters in alpha/beta space
  - Further analysis directly on non-orthogonalities in-flight and on ground test data and not the computed models.
  - Scale factor s_{exp} shall be further investigated.
  - Consolidate the analysis on dependency on s . and T_{EU}.
- Further investigation on the correlation between ASM-VFM residuals and T_{EU}.
- Continue the investigation on ASM-VFM residuals using MAGx_HR_1B data.
- Consolidate test proposal to use Heater activation to generate T gradient on boom during Dawn/Dusk orbit.
- Continue the investigation on ASM-VFM residuals using the ASM-V data to constrain the disturbance field.
- Further investigation on the possible impact the plasma–induced perturbations have on the VFM/ASM instrument.

STR:

- IBA correction model: to check the impact this model have on the field modelling

Euler Angles:

- Ionospheric/Magnetospheric currents have been found to be responsible for the apparent change of the Euler Angles. Static Euler angles are suggested to be used in L1B processing.

Data Distribution:

- L1B data produced with corrected quaternions. A TDS to be distributed to full community in preparation of the next DQW (Sept 2016)
- Burst mode ASM data delivered by IPGP to be distributed for the day 19/01/2014
- Generate RPRO MAGx_HR_1B data for the day 19/01/2014.

- A complete data package containing all available data for the day 19/01/2014 will be distributed.

IRF will deliver other two new datasets, for the benefit of all users (/Advanced folder):

- Single-probe derived electron temperatures and SC potential: this was due by end of March 2016, but the delivery suffered several delays, because of technical issues encountered in the dataset generation. Data is now almost ready and will be distributed in the coming weeks.
- Sweep mode derived electron density and temperature and SC potential (delivery date TBD).

University of Calgary updated a part of the TII preliminary dataset with newly calibrated data (Mid-April 2016).

2.4 Summary of observations for 2016, Week 17 (25/04 - 01/05)

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

- No Magnetic and Plasma Level1A and Level1B products for S/C B on 26th - 29th April, due to a VFM instrument issue. More detail on the issue in [RD.19] and in the Sections 2.1 and 4.

3. ROUTINE QUALITY CONTROL

3.1 Gaps analysis

- No Magnetic and Plasma Level1A and Level1B products for S/C B on 26th - 29th April (see Section 2.2)
- Several few seconds gaps in MAGx_CA_1B products throughout the week. Some of them seem not to be associated to gaps in telemetry. Monitoring on-going.

3.2 Orbit and Attitude Products

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

Table 1: List of events related to attitude and orbit products to be reported in the monitoring for 2016, Week 17: 25/04 - 01/05.

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^{-9})
- Visual inspection of Euler Angles derived from quaternions.

3.2.1 Position Statistics

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

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

Swarm A, 25/04 - 01/05, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
25/04	0.1	-9.9	6.2	1.07	
26/04	0.15	-7.2	7.5	1.42	
27/04	0.05	-7.9	6.8	1.29	
28/04	0.08	-10.9	9	1.28	
29/04	0.08	-8.9	7	1.12	
30/04	0.18	-6.1	7	1.15	
01/05	0.16	-8	6.4	1.16	
Swarm B, 25/04 - 01/05, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
25/04	0.07	-6.6	5.2 (X)	1.11	
26/04	0.09	-8.2	9.7	1.43	
27/04	0.15	-8.8	8	1.42	
28/04	0.13	-8.7	9.6	1.49	
29/04	0.07	-8	5.1	1.08	
30/04	0.14	-7.1	5.6	1.17	
01/05	0.19	-6.1	7.9	1.31	
Swarm C, 25/04 - 01/05, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
25/04	0.09	-6.2	6.3	1.06	
26/04	0.11	-8.9	9 (X)	1.44	
27/04	0.07	-6.8	10.6	1.3	
28/04	0.07	-9.9	7.7	1.23	
29/04	0.08	-10.6	9.4 (X)	1.08	
30/04	0.16	-8.3	6.4	1.18	
01/05	0.17	-7.6	6.7	1.17	

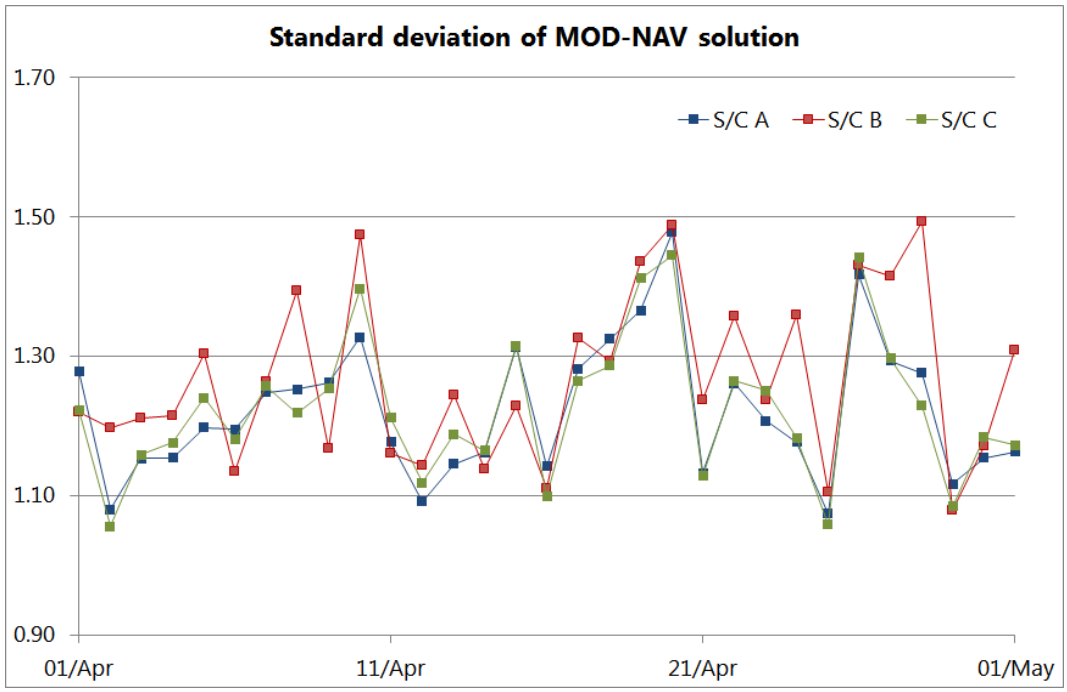


Figure 1: Plot of the standard deviation of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.

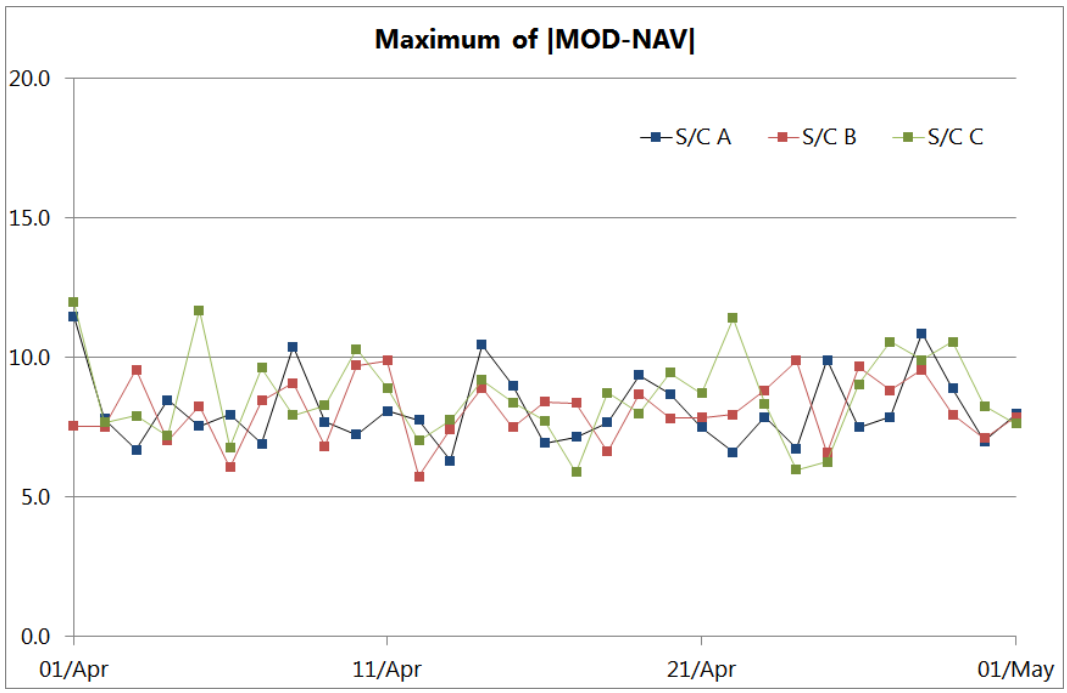


Figure 2: Plot of the maximum difference of the absolute value of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.

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 (25/04, Figure 3). From top to bottom, the plots show of MOD-NAV differences in ITFR reference frame: on X, Y and Z-axis respectively. The difference between both solutions is given in [m].

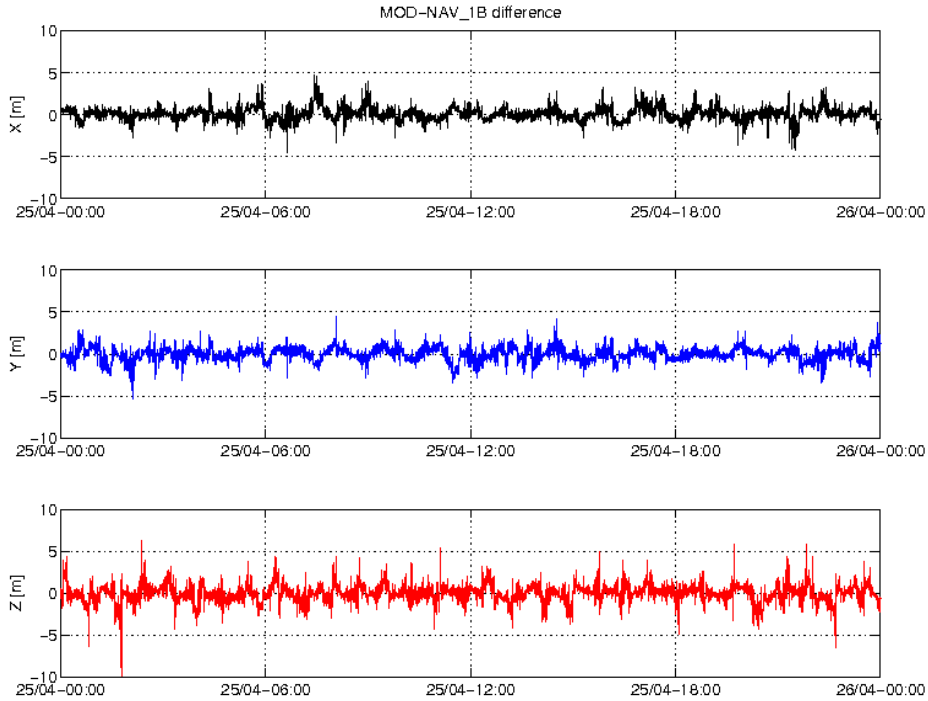


Figure 3: Difference MOD-GPSNAV, S/C A, 25/04. From top to bottom: X, Y and Z-axis

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 (25/04, Figure 4). From top to bottom, the plots show of MOD-NAV differences in ITFR reference frame: on X, Y and Z-axis respectively. The difference between both solutions is given in [m].

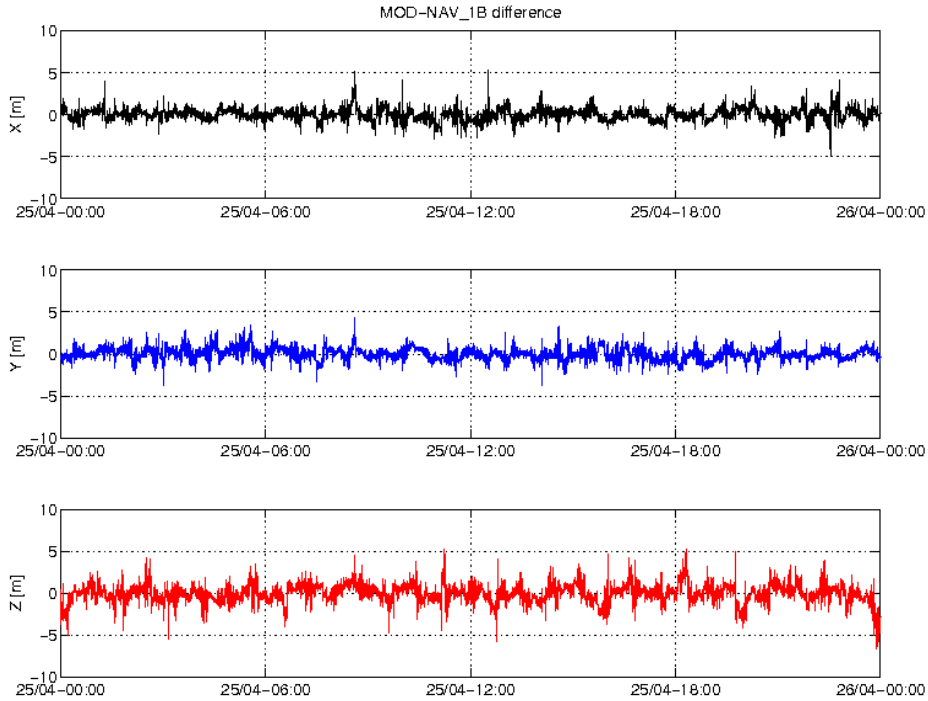


Figure 4: Difference MOD-GPSNAV, S/C B, 25/04. From top to bottom: X, Y and Z-axis

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 (25/04, Figure 5). From top to bottom, the plots show of MOD-NAV differences in ITFR reference frame: on X, Y and Z-axis respectively. The difference between both solutions is given in [m].

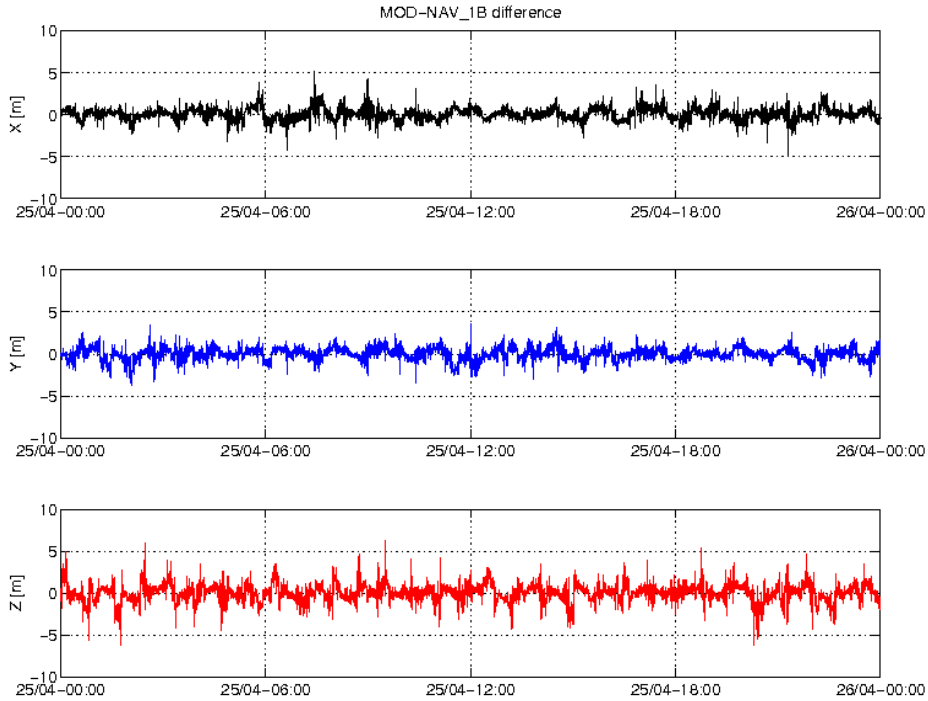


Figure 5: Difference MOD-GPSNAV, S/C C, 25/04. From top to bottom: X, Y and Z-axis

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 exceed 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.

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

Table 3: List of events related to magnetic products to be reported in the monitoring for 2016, Week 17: 25/04 - 01/05.

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

General observation:

- S/C A – violation of:
  - VFM-ASM residuals threshold on 01/05;
  - standard deviation of residuals threshold 01/05.

3.3.1.1 ASM-VFM difference statistics

In Table 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 maximum standard deviation is in the fourth column.

The ASM-VFM difference is defined as follow:

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

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

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

Swarm A, 25/04 - 01/05, ASM-VFM difference					
Day	**Max (nT)**	**Min (nT)**	**Standard deviation (nT)**	**Mean (nT)**	**Notes**
25/04	0.8	-0.82	0.32	0.131	
26/04	0.72	-0.78	0.32	0.126	
27/04	0.72	-0.73	0.31	0.118	
28/04	0.76	-0.74	0.33	0.12	
29/04	0.89	-0.84	0.36	0.137	
30/04	0.99	-0.96	0.37	0.135	
01/05	**1.21**	**-1.09**	**0.44**	0.152	
Swarm B, 25/04 - 01/05, ASM-VFM difference					
Day	**Max (nT)**	**Min (nT)**	**Standard deviation (nT)**	**Mean (nT)**	**Notes**
25/04	0.57	-0.8	0.26	-0.093	
26/04	0	0	0	0	Missing production, due to instrument issue
27/04	0	0	0	0	
28/04	0	0	0	0	
29/04	0	0	0	0	
30/04	0.71	-0.87	0.29	-0.11	
01/05	0.6	-0.8	0.28	-0.128	

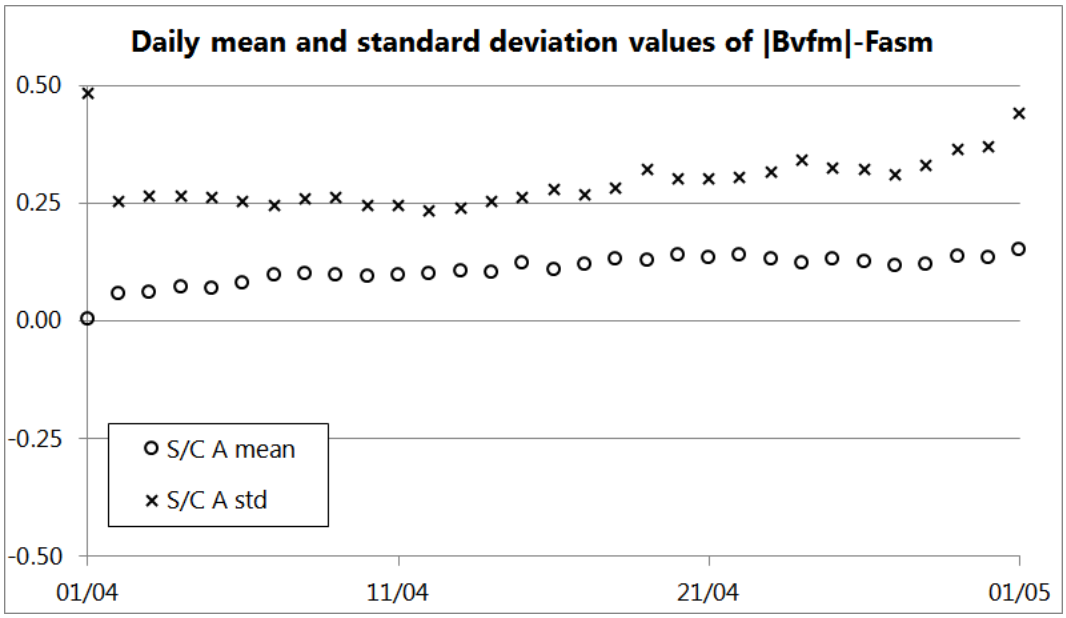


Figure 6: Daily mean and standard deviation values of ASM-VFM residuals (defined as $dF=|B_{VFM}|-F_{ASM}$) for S/C A.

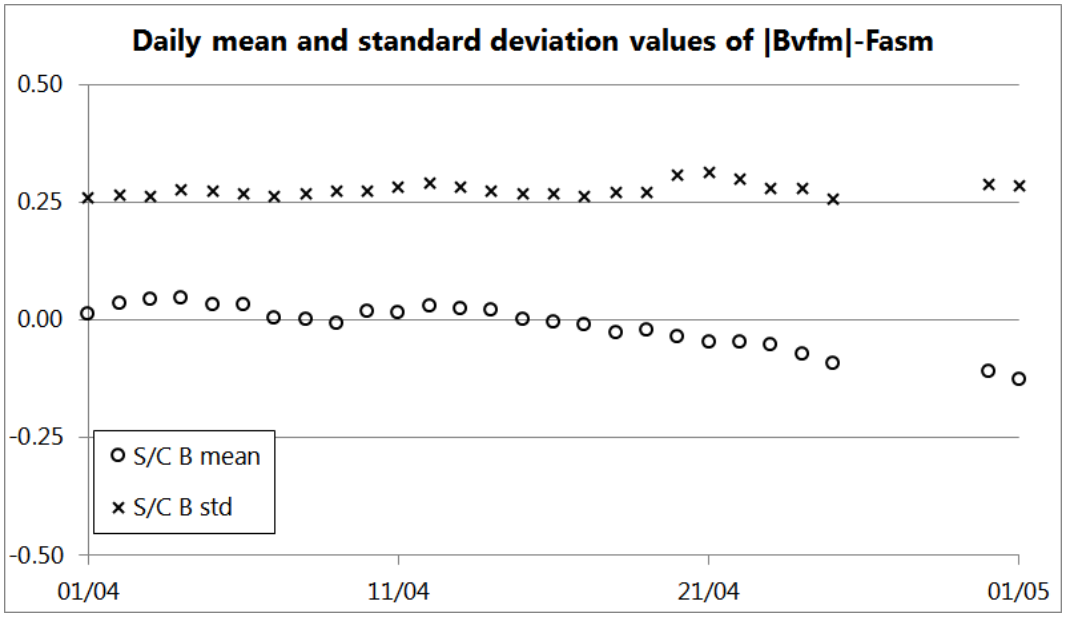


Figure 7: Daily mean and standard deviation values of ASM-VFM residuals (defined as $dF=|B_{VFM}|-F_{ASM}$) for S/C B.

3.3.1.2 Swarm A

The daily peak-to-peak difference around the week stays within [-1.09 - 1.21] nT. Below follow two plots of such differences for current week (Figure 8).

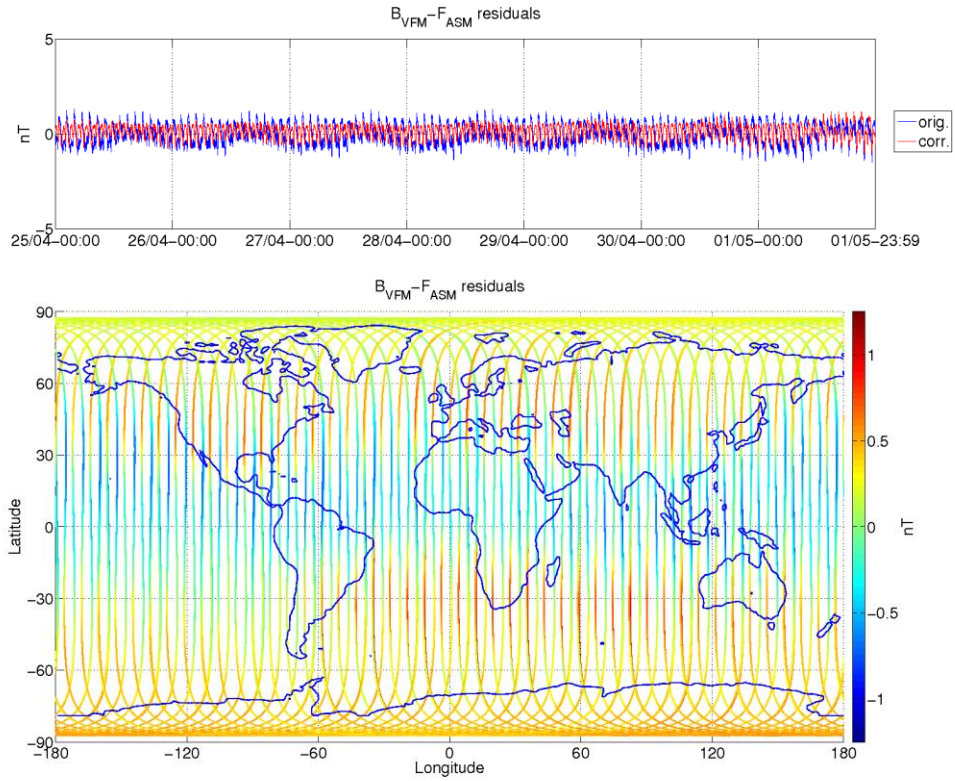


Figure 8: ASM-VFM residuals for S/C A, during monitoring period 25/04-01/05. In top figure are plotted: difference between |B_VFM| and F_ASM (without dB_Sun correction) (blue colour), and the residuals with dB_Sun corrections (red colour). In bottom figure residuals are presented on the world map.

3.3.1.3 Swarm B

The daily peak-to-peak difference around the week stays within [0.71] nT. Below follow two plots of such differences for current week (Figure 9).

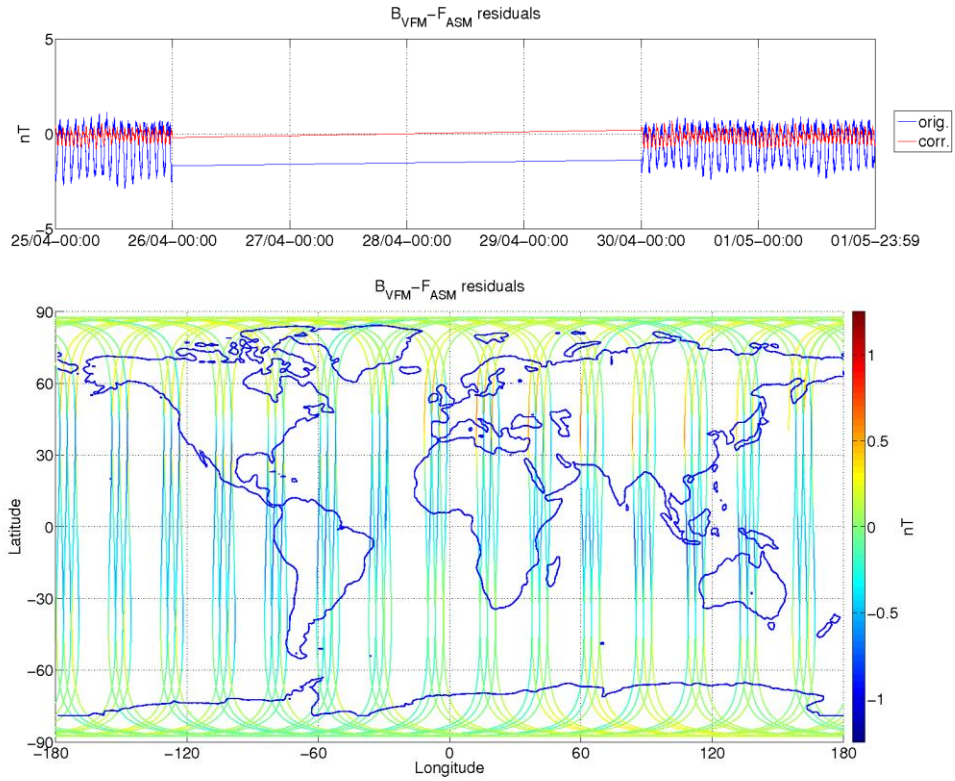


Figure 9: ASM-VFM residuals for S/C B, during monitoring period 25/04-01/05. In top figure are plotted: difference between |B_VFM| and F_ASM (without dB_Sun correction) (blue colour), and the residuals with dB_Sun corrections (red colour). In bottom figure residuals are presented on the world map.

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)

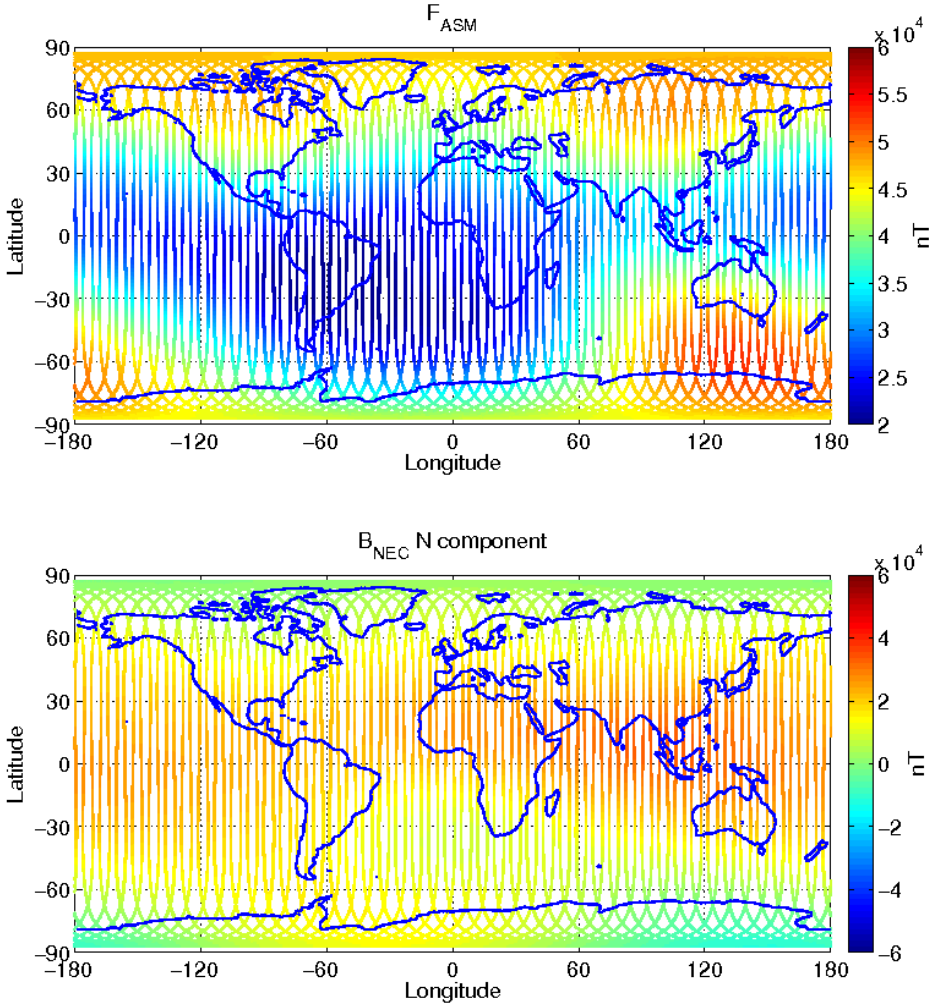
The VFM instrument parameters important for monitoring the instrument health are the VFM sensor temperatures: T_CDC, T_CSC and T_EU.

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 17 for S/C A can be seen in Figure 10 below.



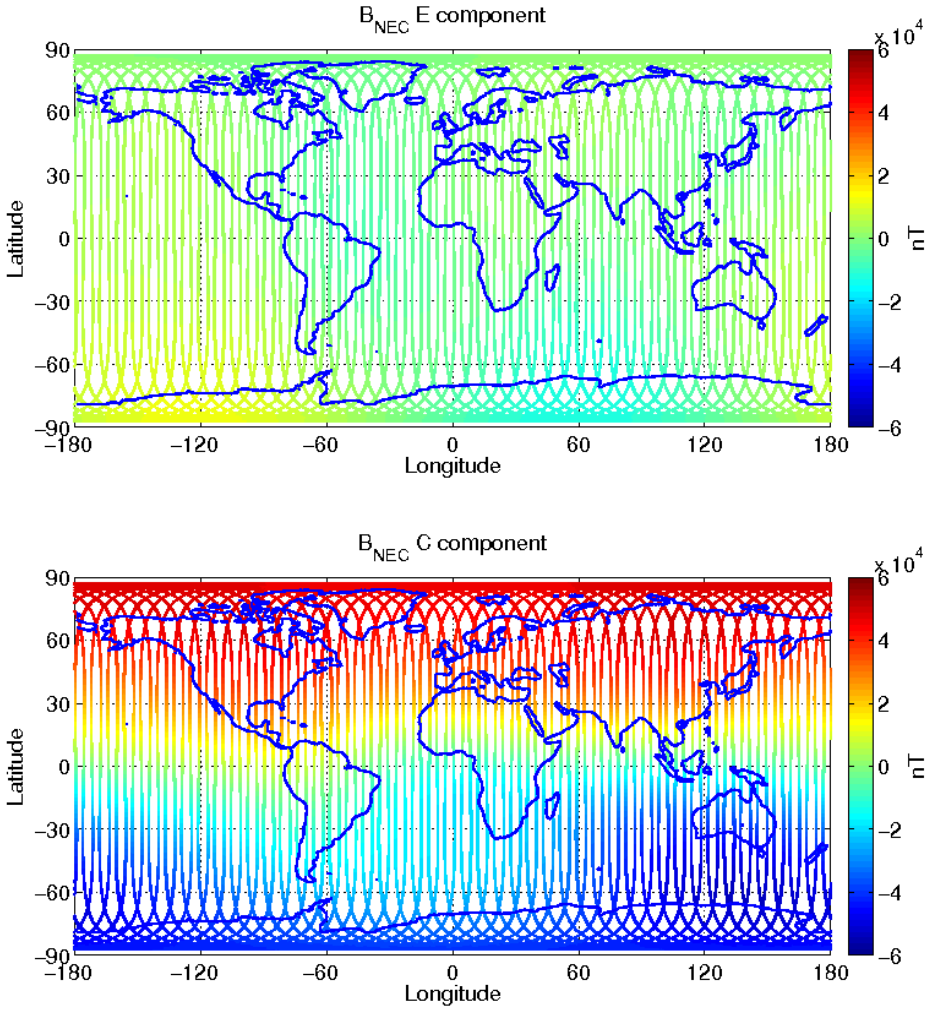
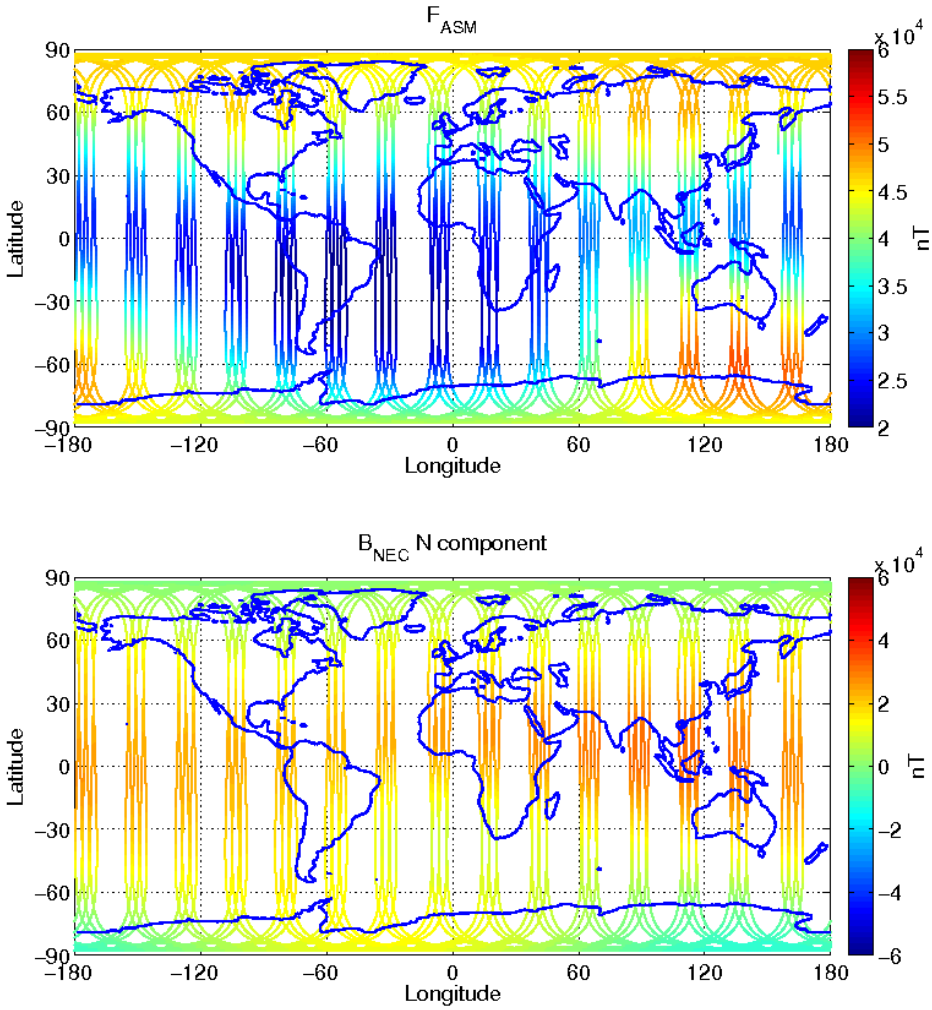


Figure 10: S/C A, world map plots of the geomagnetic field and components measured during monitoring period 25/04-01/05. From top to bottom: F-magnetic field from ASM measurement, B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement.

3.3.4.2 Swarm B

Map plots of magnetic field measurement for week 17 for S/C B can be seen in Figure 11 below.



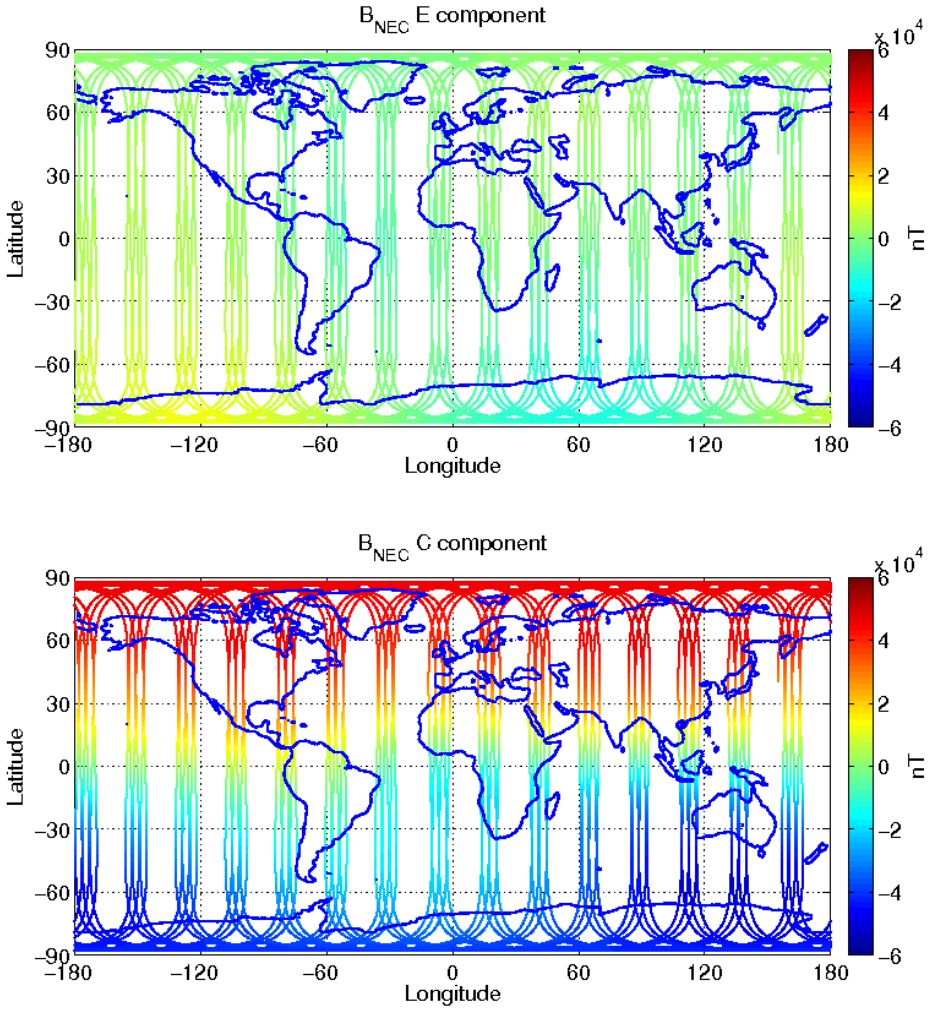


Figure 11: S/C B, world map plots of the geomagnetic field and components measured during monitoring period 25/04-01/05. From top to bottom: F-magnetic field from ASM measurement, B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement.

3.3.4.3 Swarm C

Map plots of magnetic field measurement for week 17 for S/C C can be seen in Figure 12.

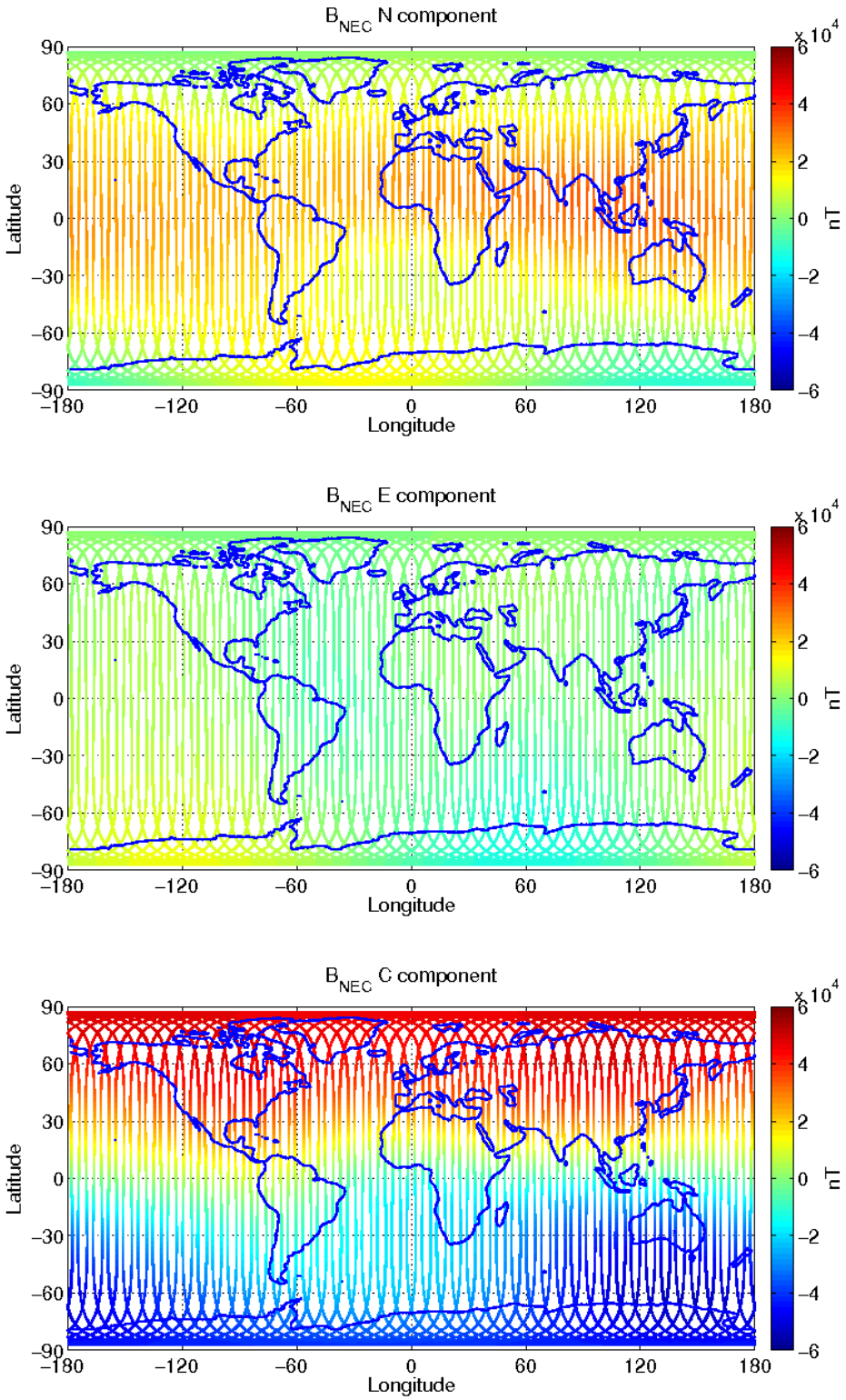


Figure 12: S/C C, world map plots of the geomagnetic field and components measured during monitoring period 25/04-01/05. From top to bottom: B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement.

3.3.5 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 13, Figure 15 and Figure 17 show field residuals $dB=B_{NEC} - B_{Chaos}$ (all versus co-latitude in degrees), from top to bottom: 1) Br, 2) $B\theta$ and 3) $B\varphi$.

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 14, Figure 16 and Figure 18 show, from top to bottom, the time series on 25/04 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 +/- 200 nT.

3.3.5.1 Swarm A

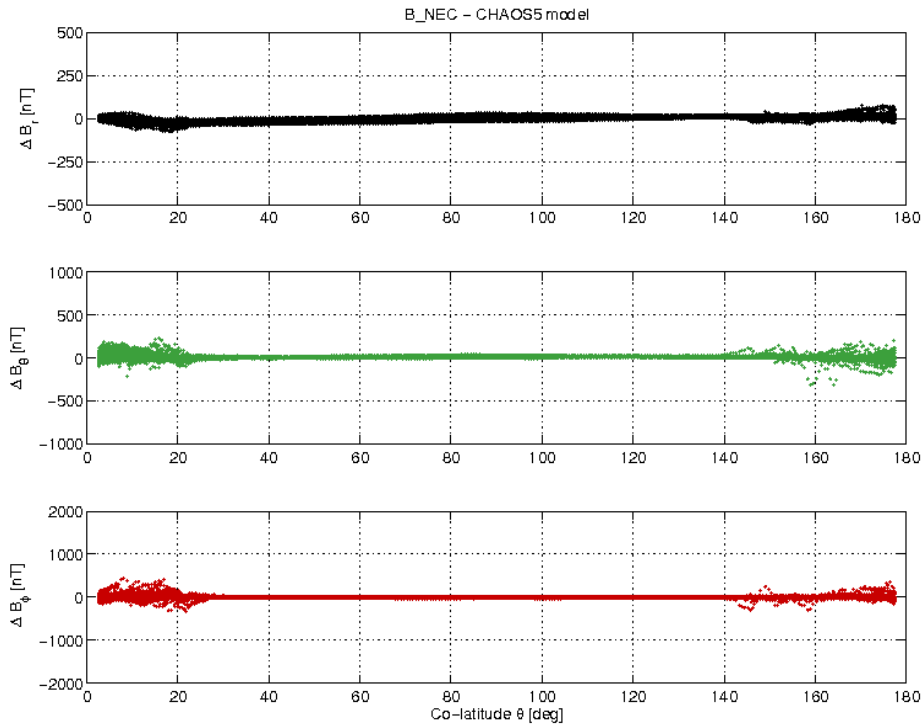


Figure 13: S/C A day 25/04 B_{NEC} - B_{Chaos} vs colatitude.

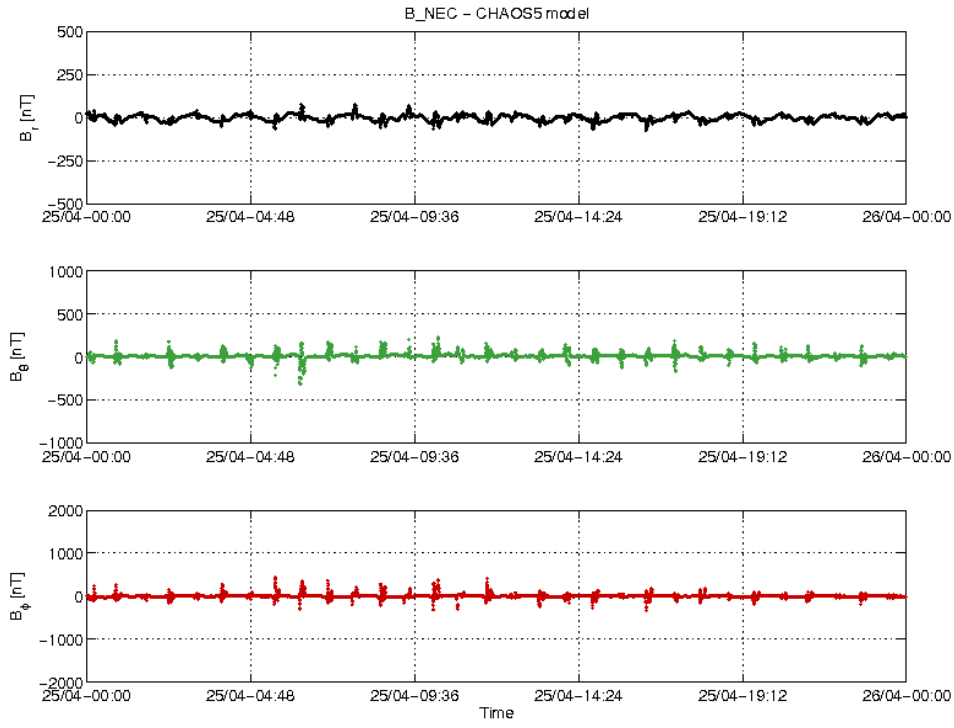


Figure 14: S/C A day 25/04: time series of B_{NEC} – B_{Chaos} residuals.

3.3.5.2 Swarm B

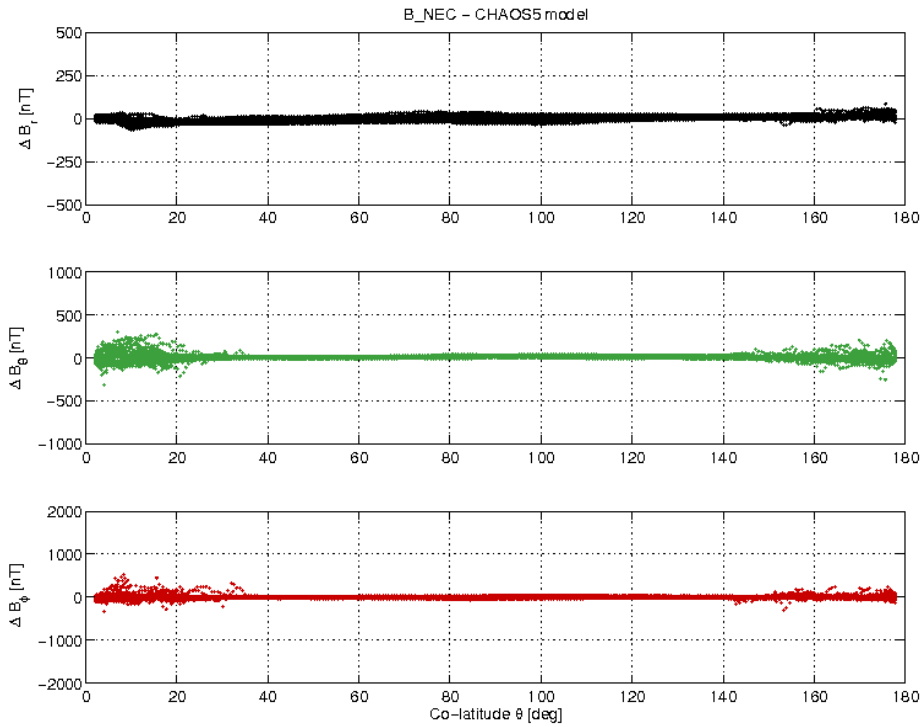


Figure 15: S/C B day 25/04 B_{NEC} - B_{Chaos} difference vs colatitude.

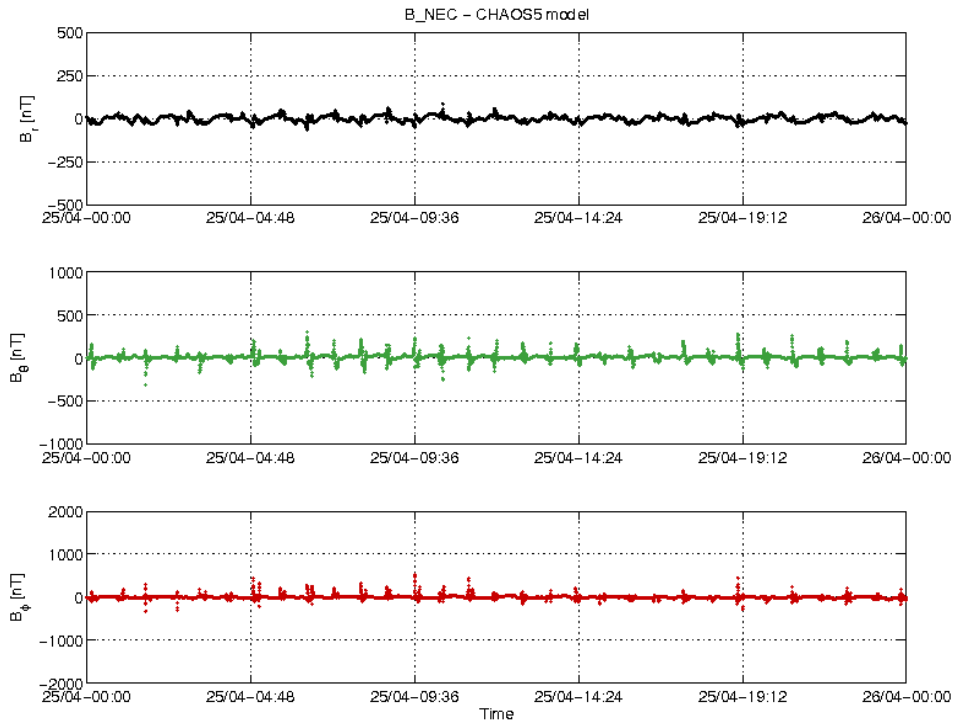


Figure 16 S/C B day 25/04 time series of B_{NEC} – B_{Chaos} residuals.

3.3.5.3 Swarm C

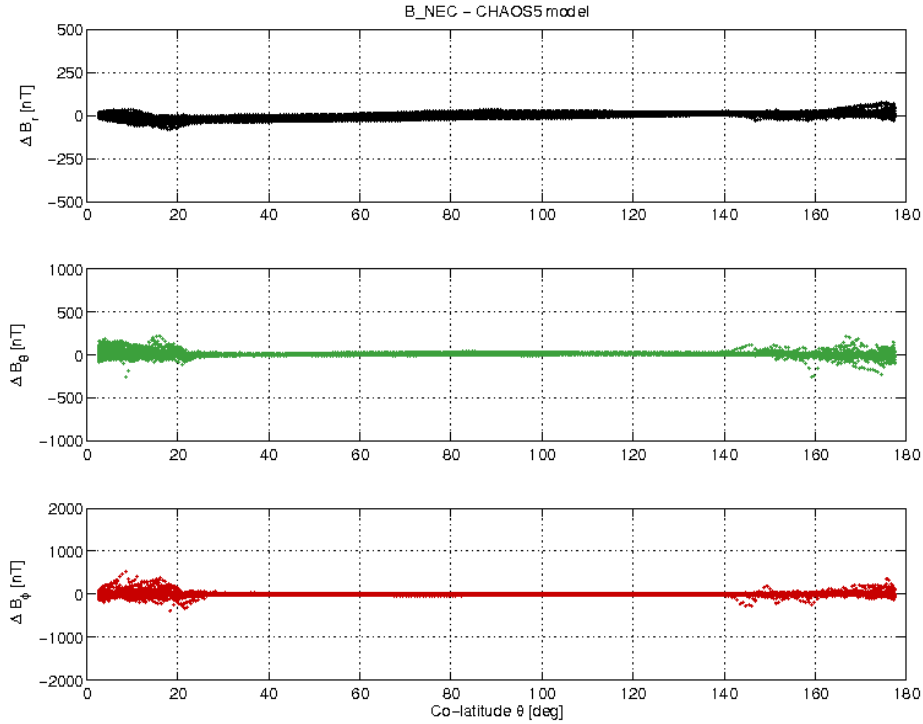


Figure 17 S/C C day 25/04 B_{NEC} - B_{Chaos} difference vs colatitude.

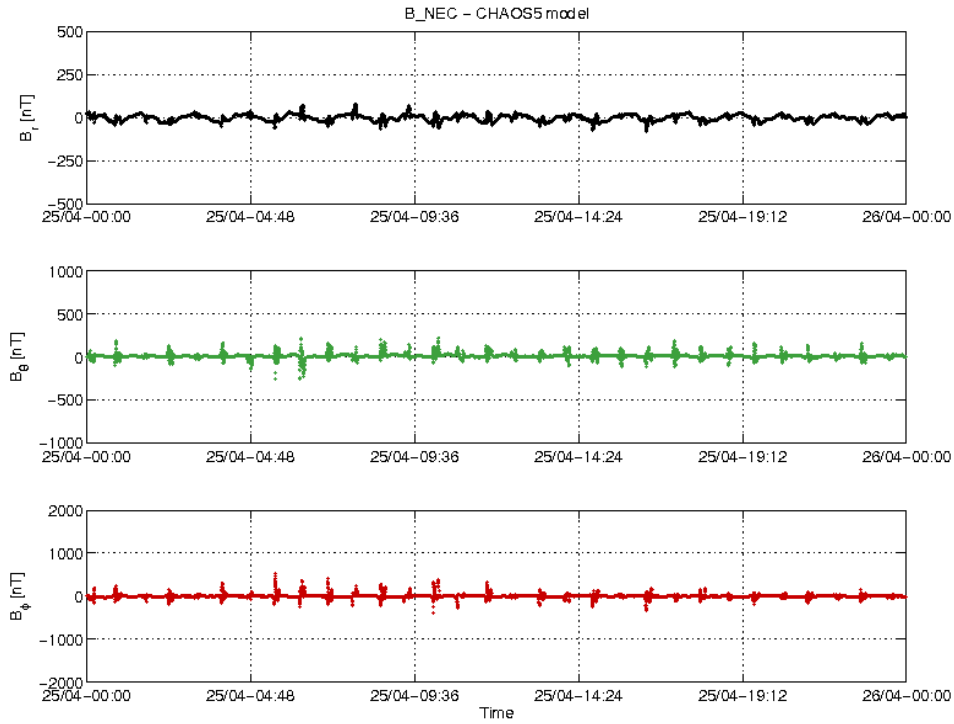


Figure 18 S/C C day 25/04 time series of $B_{NEC} - B_{Chaos}$ residuals.

3.3.6 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 ±10° latitude have been considered. Figure 19, Figure 20 and Figure 21 show the daily standard deviation of the second derivative of B_{NEC} and B_{VFM} of the last month for S/C A, B, and C respectively. Please note that the y-axis in all the three plots is in linear scale from 0 to 100, and in logarithmic scale from 100 on. The spikes (2^{nd} derivative value above 100) is in all cases caused by artificial spike introduced during quaternions interpolation from 1Hz to 50Hz (under investigation).

Disregarding spikes (second derivative above 100) the most disturbed components are:

- East and Centre components of B_{NEC}, and Y in B_{VFM} for S/C A and B.
- On S/C C all components are almost equally disturbed.

3.3.6.1 Swarm A

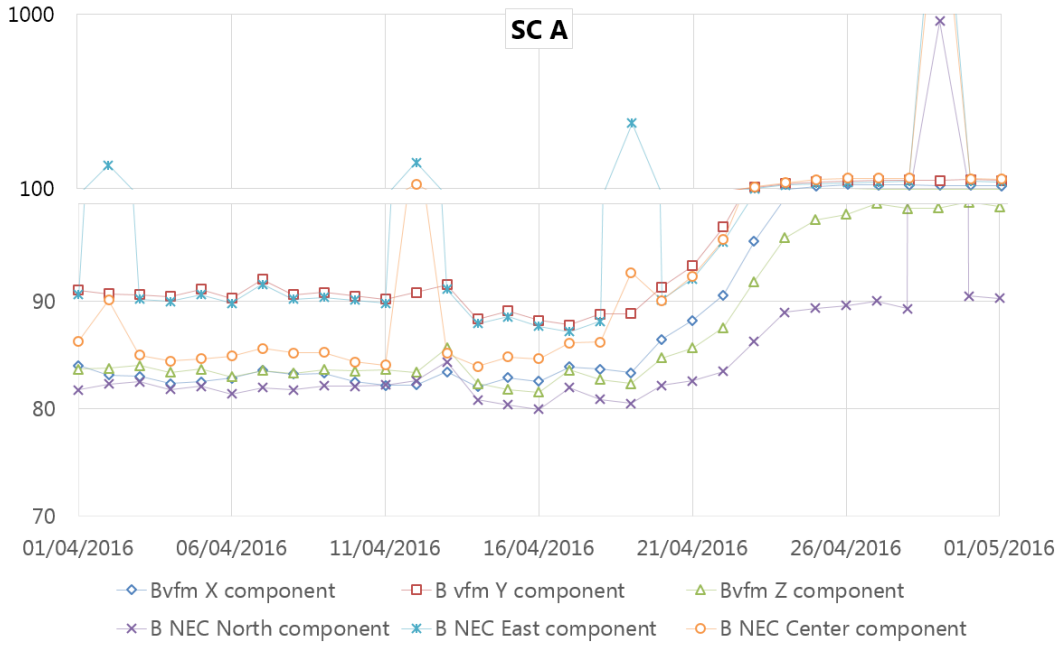


Figure 19: Plot of standard deviation of B components in VFM and NEC frames. Please note the mixed (linear + logarithmic) vertical axis (in range 100-1000 is given in logarithmic scale). In the last week the least disturbed components is North in NEC frame and Z in VFM frame.

Swarm B

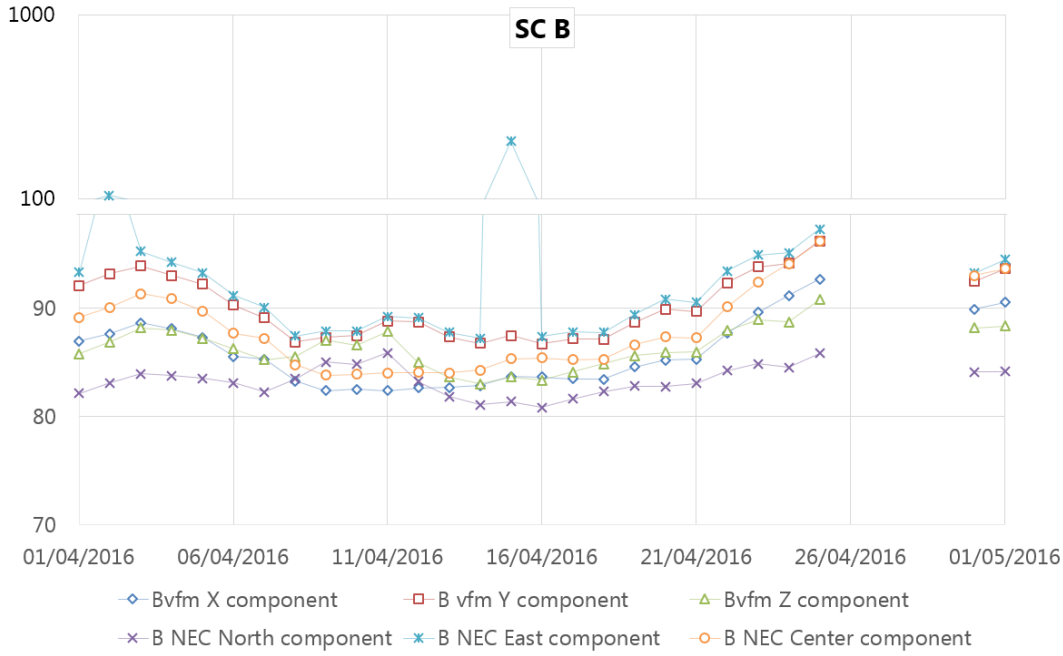


Figure 20: Plot of standard deviation of B components in VFM and NEC frames. Please note the mixed (linear + logarithmic) vertical axis (in range 100-1000 is given in logarithmic scale). The most disturbed components are East and Centre in NEC frame and Y in VFM frame.

3.3.6.2 Swarm C

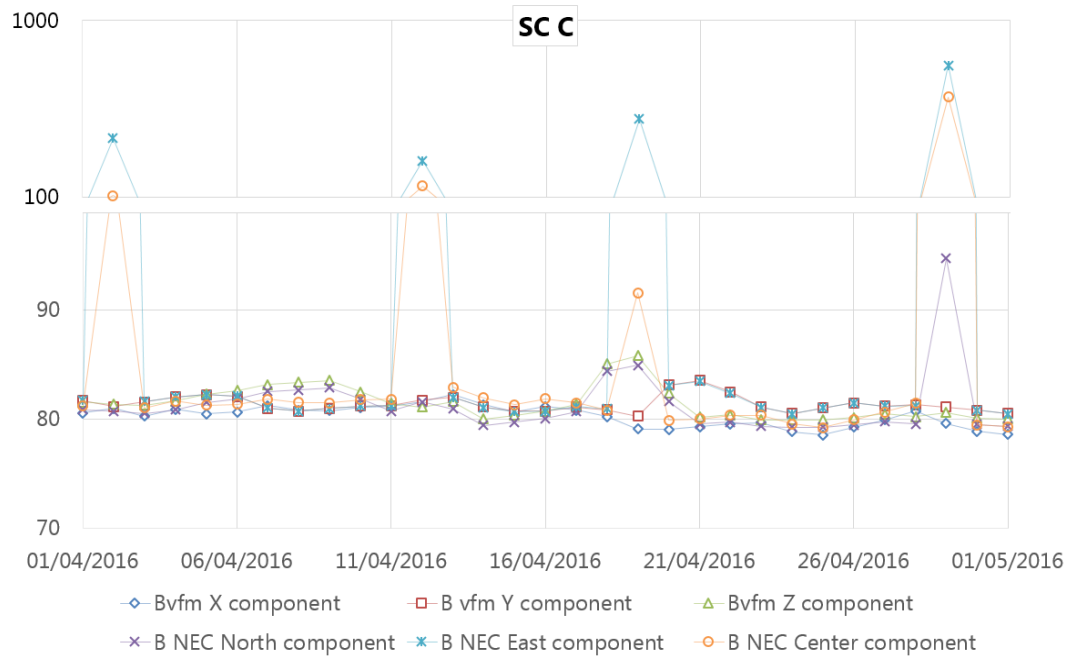


Figure 21: Plot of standard deviation of B components in VFM and NEC frames. Please note the mixed (linear + logarithmic) vertical axis (in range 100-1000 is given in logarithmic scale).

4. ON-DEMAND ANALYSIS

4.1 VFM noise analysis

The noise of VFM 50Hz measurement is assessed and the results for all S/C are presented below. The noise is assessed in the following way: each component of B_VFM is processed with a 3rd order Butterworth high pass filter with cut-off frequency of 0.5Hz. To assess the noise only filtered data within Latitude band +/-10° are selected and daily RMS is calculated.

In figures below RMS of each filtered component is plotted, for the three S/C. It can be noted that for S/C A the noise has increased over last week for all components. However the increase is not high and situation can be considered as nominal. For S/C B, in spite of the anomaly reported in Sect. 2.1, the time series seems not to show any particular behaviour. Occasionally, in particular for Swarm A and C, spikes of the VFM Bx component can be observed, up to 40 pT. We are considering further tuning of the filter constraints, as we have the suspect that a cut-off frequency at 0.5 Hz still allows much of geophysical signals to "contaminate" the noise series; also the latitude band at +/-10 degrees could be questionable, and we might consider to select only quiet intervals on the night side, and maybe more mid-latitude.

In any case, the RMS of the noise is overall in line with the reports of the instrument team.

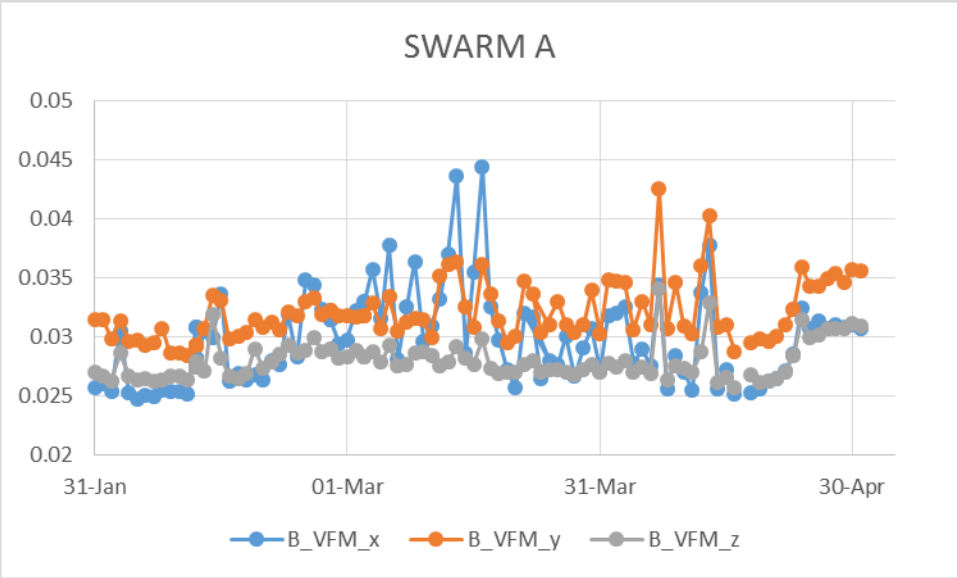


Figure 22 S/C A, RMS of all components of B_VFM after high pass filtering with 3rd order Butterworth high pass filter. RMS calculated only for +/-10° latitude band.

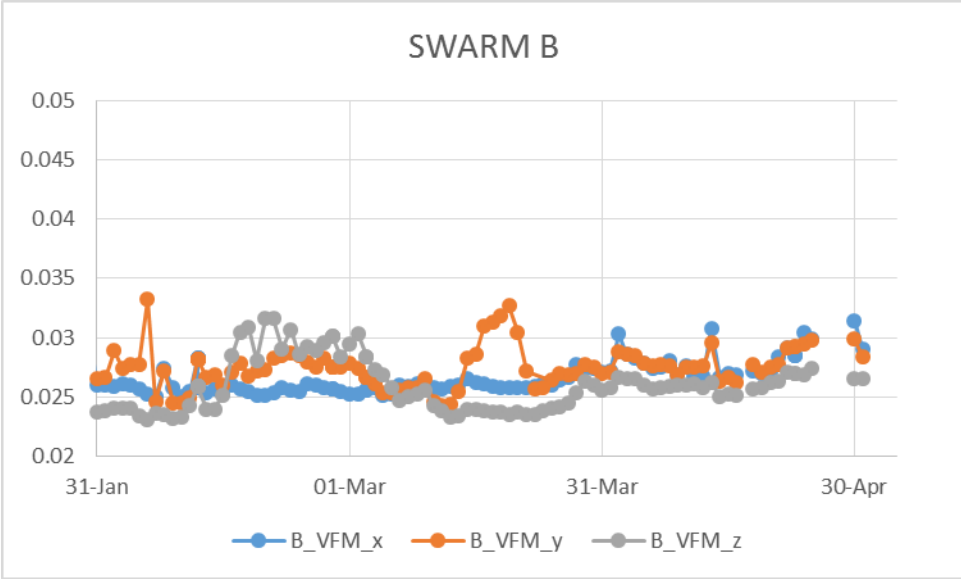


Figure 23 S/C B, RMS of all components of B_VFM after high pass filtering with 3rd order Butterworth high pass filter. RMS calculated only for +/-10° latitude band.

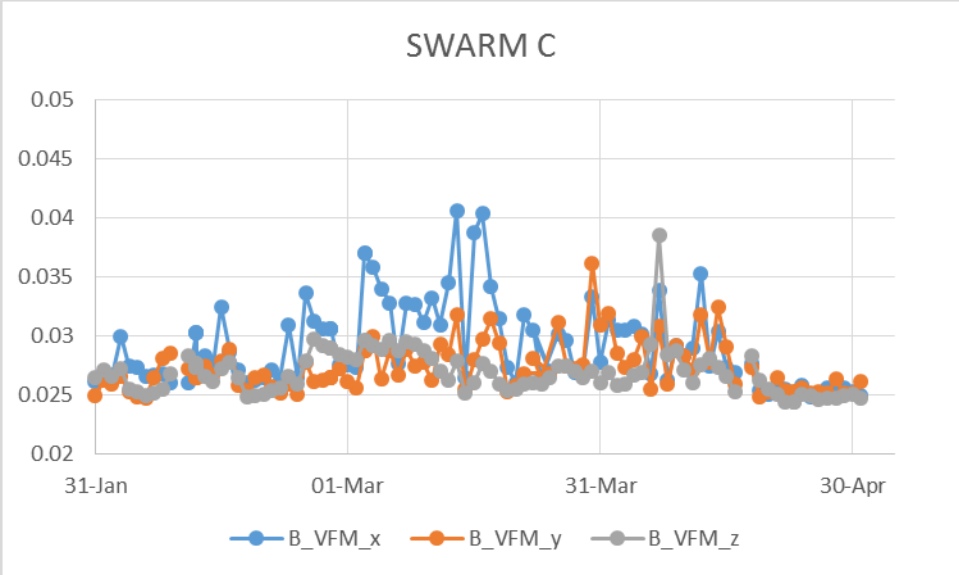


Figure 24 S/C C, RMS of all components of B_VFM after high pass filtering with 3rd order Butterworth high pass filter. RMS calculated only for +/-10° latitude band.

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