Customer	**:**	**ESRIN**	**Document Ref**	**:**	**IDEAS+-SER-OQC-REP-2071**
Contract No	**:**	**4000111304/14/I-AM**	**Issue Date**	**:**	**25 March 2016**
WP No	**:**	**6110**	**Issue**	**:**	**1.0**

IDEAS+ Swarm Weekly Report 2016/10: 2016/03/07 - 2016/03/13

Abstract : This is the **Instrument Data Quality Evaluation and Analysis Service Plus** (IDEAS+) Swarm Weekly report on Swarm products quality, covering the period from 07 March to 13 March 2016.

Author : Igino Coco, Jan Miedzik and Enkelejda Qamili on behalf of Swarm IDEAS+ Team

Approval : Lidia Saavedra de Miguel
IDEAS+ Science and Ops. Coordinator

Distribution : ESA/ESRIN EOP-GMQ
ESA/ESRIN EOP-GM Swarm MM
IDEAS+ Leadership Team
IDEAS+ subcontractors
ESA/ESTEC Swarm PLSO
ESA/ESOC Swarm FOS

TABLE OF CONTENTS

This page intentionally left blank.

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	25 Mar 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;
>
> 2.b. If the observation/analysis does not lead to an anomaly or the investigation shall be escalated to other entities (PLSO/industry, ESL, 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 3.16.p2, L2-Cat2 1.15.p4.
- 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: CCDB 0010 (04/02/2016), 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

2. SUMMARY OF THE OBSERVATIONS

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

Nothing to report

2.2 Plan for operational processor updates

L1BOP: The L1BOP 3.17 has been released by GMV the 15^{th} of February. The PDGS team have finished the execution of all the tests. In the coming days will follow the validation of all the products.

In the meantime, two changes were decided to be implemented into the MAGNET processor, i.e.:

- 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

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: A new patch (p5) of the L2 Cat-2 OP v01.15 has been released by GMV the 23^{rd} of March. This delivery impacts the computation of the FAC uncertainties. The PDGS team has put the validation activity in pipeline after the conclusion of the L1BOP 3.17 validation. 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_{β} 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 have delivered an updated “16 Hz Faceplate plasma density” dataset. This dataset has been published in the ESA ftp server (/Advanced folder) accessible to all users. This dataset cover from beginning of October 2014 to end February 2016 for all spacecraft.

IRF is about to deliver other two new datasets, for the benefit of expert users (/Advanced folder):

- Single-probe derived electron temperatures and SC potential (by end of March)
- Sweep mode derived electron density and temperature and SC potential (by end of March).

Moreover, investigations are on-going with the help of GFZ, on the spike occurrences on the electron temperature: we have provided GFZ with HK_BUS_1A products in CDF, containing the solar panel currents, in order to investigate possible correlation of the spikes with solar illumination and/or currents activations.

2.4 Summary of observations for 2016, Week 10 (07/03 - 13/03)

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

- **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. ROUTINE QUALITY CONTROL

3.1 Gaps analysis

- **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 10: 07/03 - 13/03.

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, 07/03 - 13/03, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
07/03	0.06	-8.6 (Y)	10.6	1.37	
08/03	0.13	-6.7	10.7	1.28	
09/03	0.04	-8	6.8 (X)	1.13	
10/03	0.05	-8.8	8.7	1.3	
11/03	0.15	-6.7	11.2	1.52	
12/03	0.11	-7.3	7 (Y)	1.24	
13/03	0.07	-9.1	8.4	1.28	
Swarm B, 07/03 - 13/03, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
07/03	0.15	-7.7	9.2	1.3	
08/03	0.06	-6.3 (X)	7.4	1.25	
09/03	0.07	-7.3	5.5 (Y)	1.15	
10/03	0.14	-7.6	6.9	1.25	
11/03	0.15	-9	9.1	1.63	
12/03	0.06	-11.1	9.2 (X)	1.22	
13/03	0.17	-12.2	12.2	1.3	
Swarm C, 07/03 - 13/03, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
07/03	0.12	-7.3	7.7	1.36	
08/03	0.11	-7	10.2	1.27	
09/03	0.05	-8.6 (Y)	12.2	1.15	
10/03	0.05	-7.9	10.2	1.26	
11/03	0.2	-6.8	8.1	1.51	
12/03	0.09	-7.4	7.6 (X)	1.27	
13/03	0.1	-7.3	9.5	1.27	

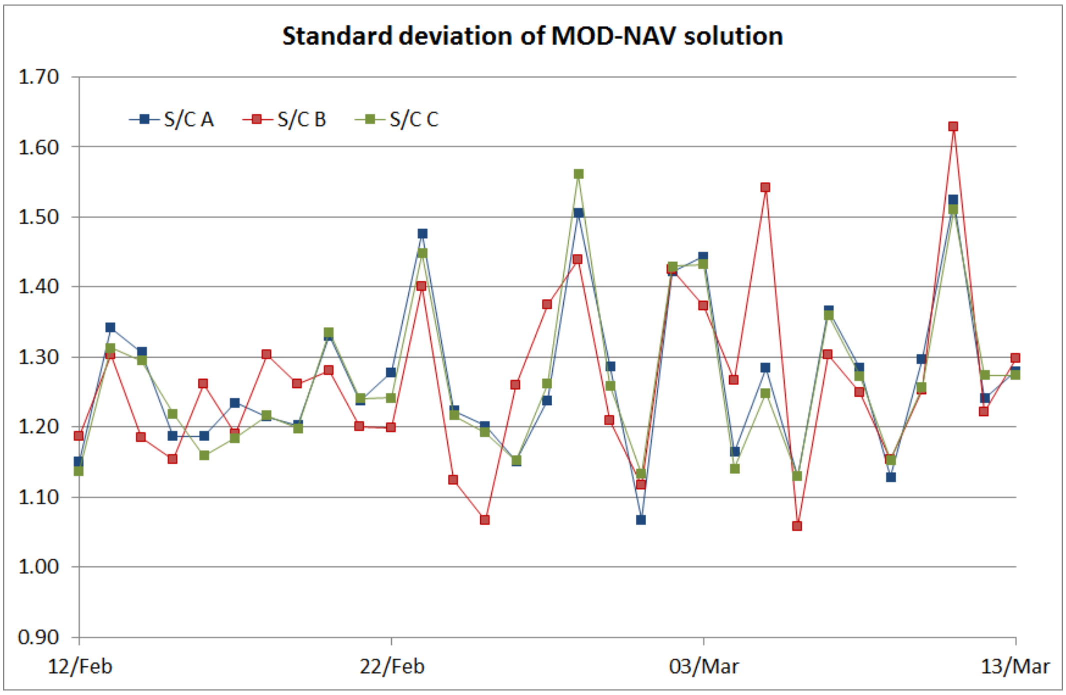


Figure 1: Plot of the standard deviation of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.

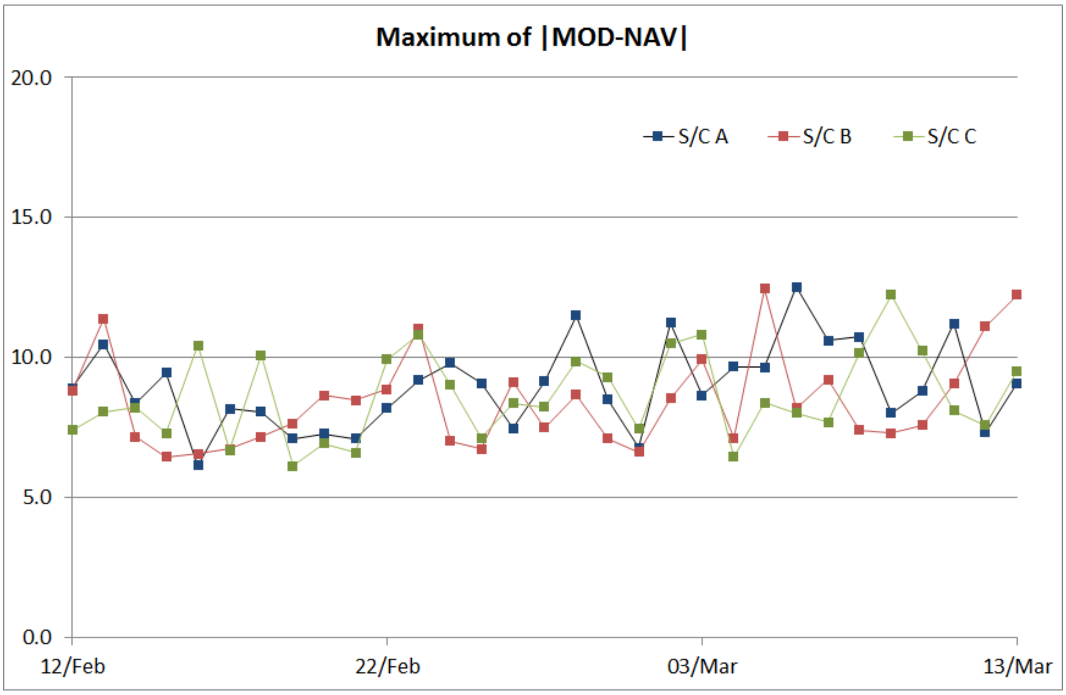


Figure 2: Plot of the maximum difference of the absolute value of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.

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 (07/03, 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].

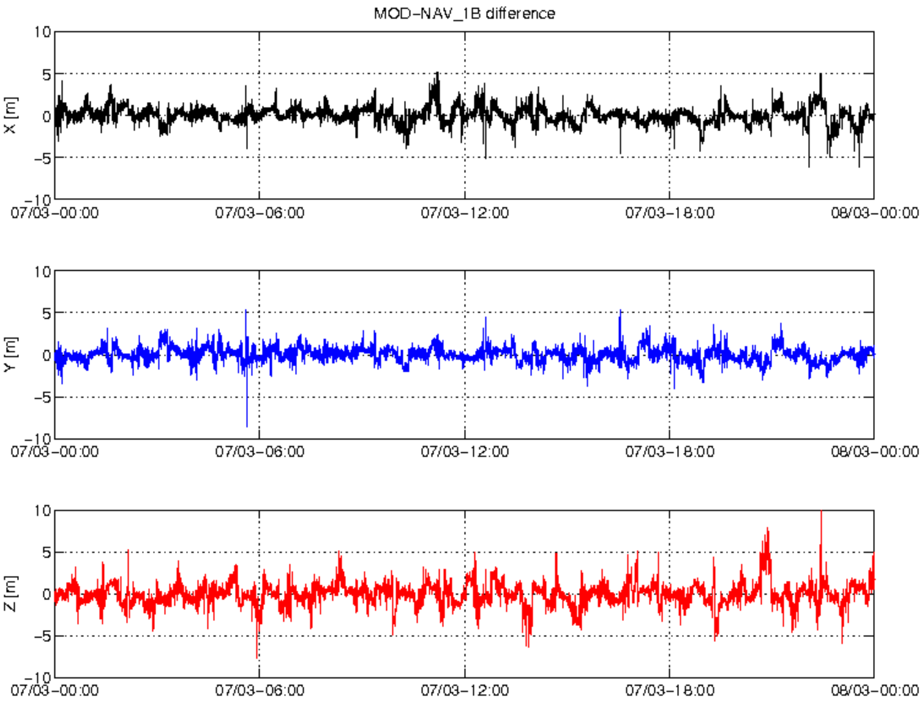


Figure 3: Difference MOD-GPSNAV, S/C A, 07/03. From top to bottom: X, Y and Z-axis

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 (07/03, 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].

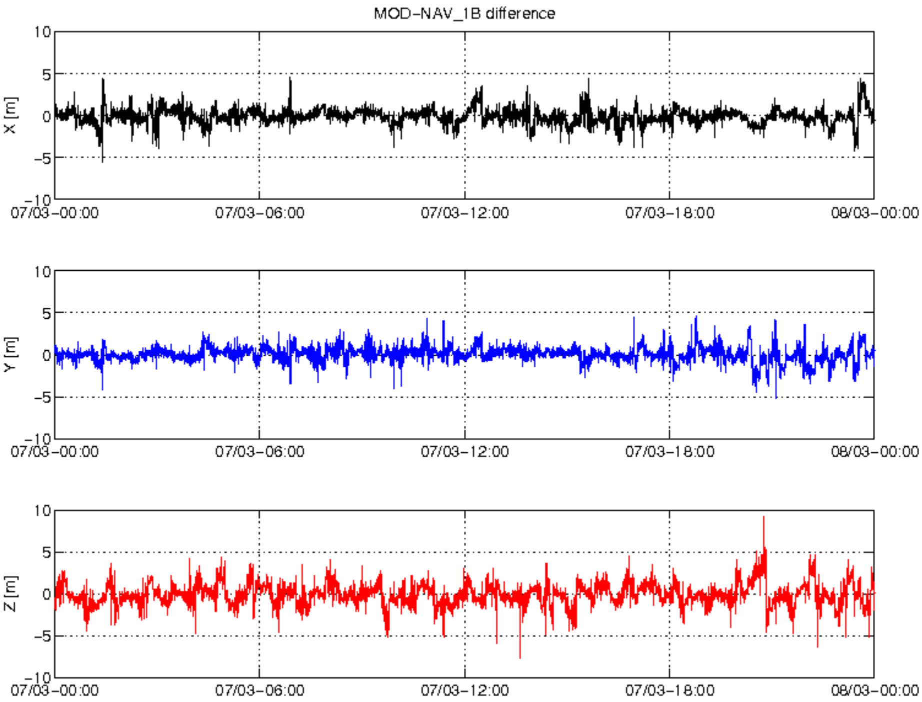


Figure 4: Difference MOD-GPSNAV, S/C B, 07/03. From top to bottom: X, Y and Z-axis

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 (07/03, 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].

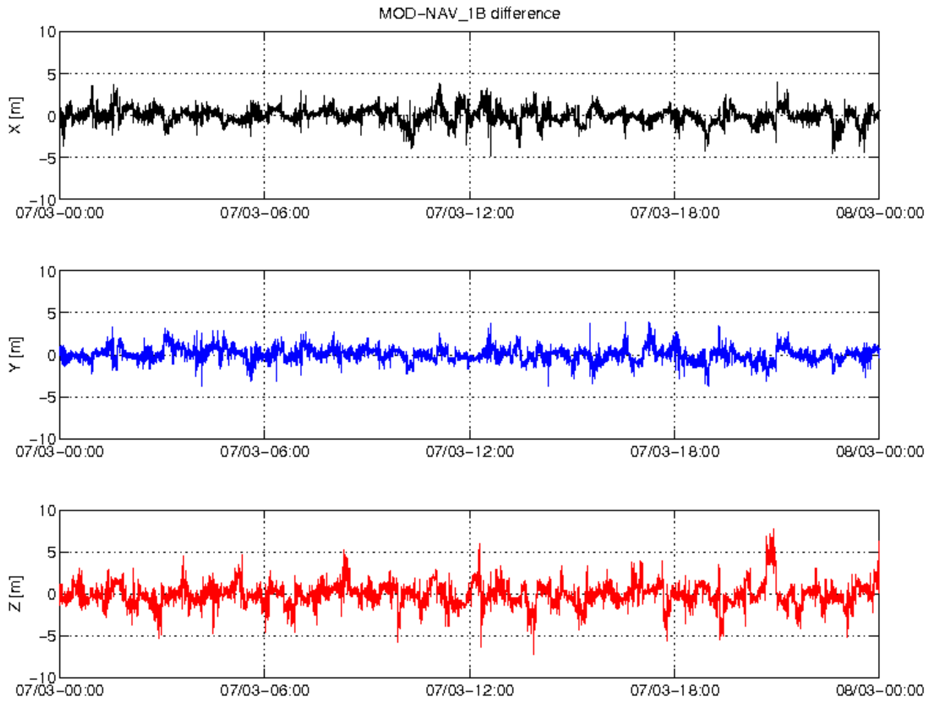


Figure 5: Difference MOD-GPSNAV, S/C C, 07/03. From top to bottom: X, Y and Z-axis

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 and ASM temperature.
- VFM instrument monitoring: temperatures.
- 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).

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 10: 07/03 - 13/03.

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 B – violation of:
    - VFM-ASM residuals threshold on-07/03, 09/03, 10/03, 11/03;
    - Standard deviation of residuals threshold 10/03, 11/03.

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, 07/03 - 13/03, ASM-VFM difference					
Day	**Max (nT)**	**Min (nT)**	**Standard deviation (nT)**	**Mean (nT)**	**Notes**
07/03	0.74	-0.52	0.25	0.116	
08/03	0.7	-0.6	0.25	0.092	
09/03	0.65	-0.58	0.25	0.075	
10/03	0.63	-0.7	0.25	0.085	
11/03	0.61	-0.6	0.23	0.076	
12/03	0.59	-0.54	0.21	0.07	
13/03	0.55	-0.69	0.21	0.062	
Swarm B, 07/03 - 13/03, ASM-VFM difference					
Day	**Max (nT)**	**Min (nT)**	**Standard deviation (nT)**	**Mean (nT)**	**Notes**
07/03	0.75	**-1**	0.33	-0.049	
08/03	0.8	-0.93	0.32	-0.028	
09/03	0.81	**-1.08**	0.39	-0.048	
10/03	0.76	**-1.07**	**0.4**	-0.026	
11/03	0.79	**-1.07**	**0.41**	-0.017	
12/03	0.75	-0.96	0.38	-0.003	
13/03	0.66	-0.89	0.32	-0.009	

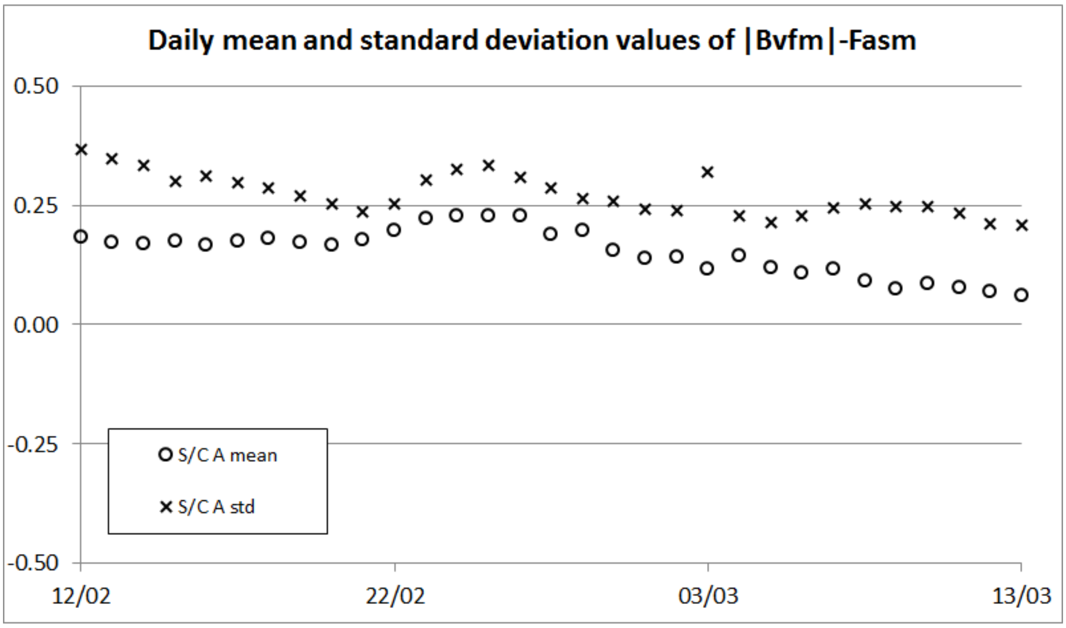


Figure 6: Daily mean and standard deviation values of ASM-VFM residuals (defined as $dF=|B_{VFM}|-F_{ASM}$) for S/C A.

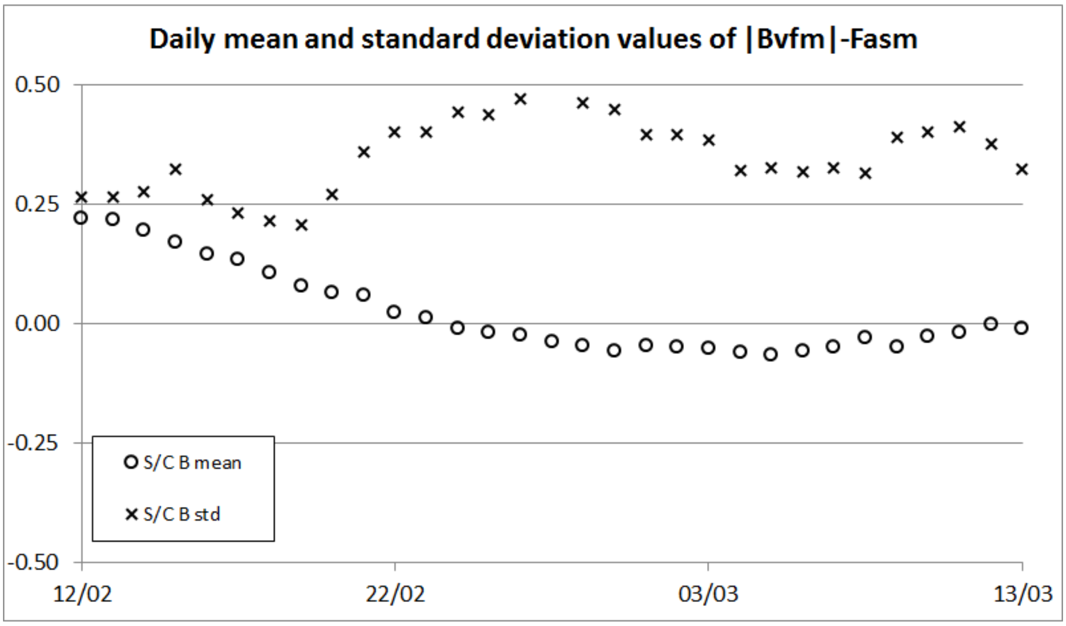


Figure 7: Daily mean and standard deviation values of ASM-VFM residuals (defined as $dF=|B_{VFM}|-F_{ASM}$) for S/C B.

3.3.1.2 Swarm A

The daily peak-to-peak difference around the week stays within [-0.7, 0.74] nT. Below follow two plots of such differences for current week (Figure 8).

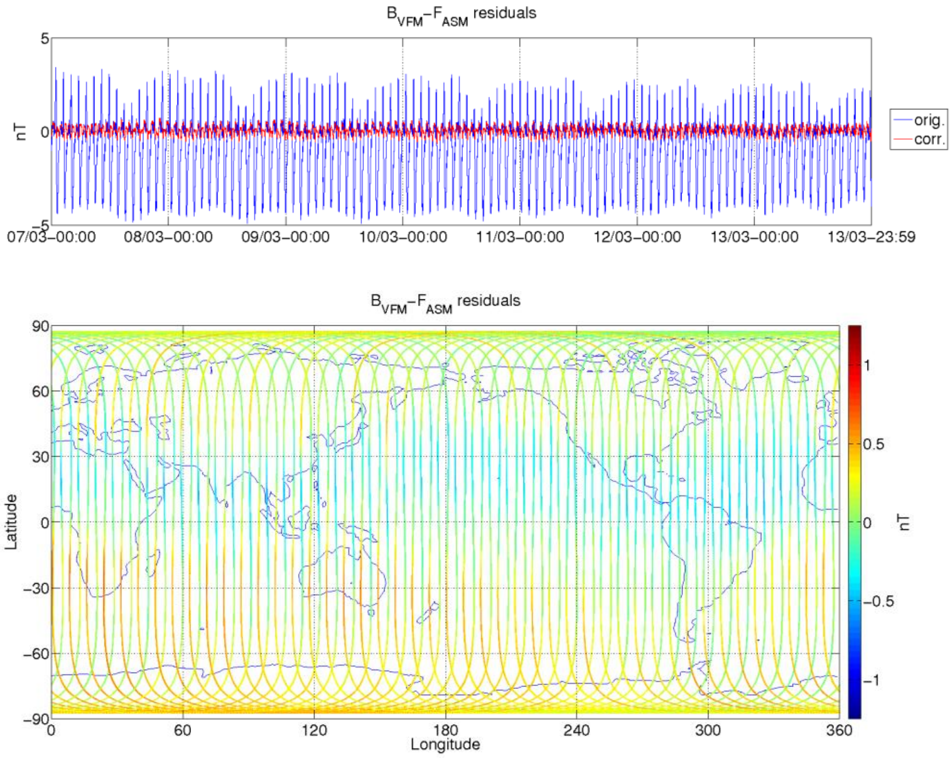


Figure 8: ASM-VFM residuals for S/C A, during monitoring period 07/03-13/03. In top figure are plotted: difference between |B_VFM| and F_ASM (without dB_Sun correction) (blue colour), and the residuals with dB_Sun corrections (red colour). In bottom figure residuals are presented on the world map.

3.3.1.3 Swarm B

The daily peak-to-peak difference around the week stays within [-1.08, 0.81] nT. Below follow two plots of such differences for current week (Figure 9).

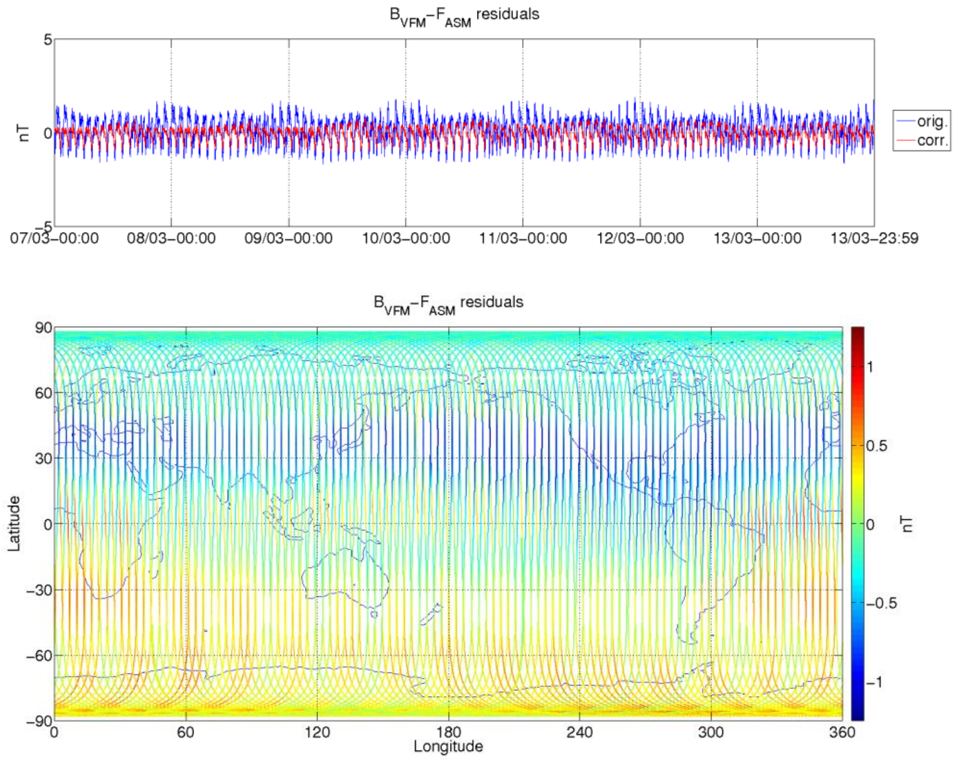


Figure 9: ASM-VFM residuals for S/C B, during monitoring period 07/03-13/03. In top figure are plotted: difference between |B_VFM| and F_ASM (without dB_Sun correction) (blue colour), and the residuals with dB_Sun corrections (red colour). In bottom figure residuals are presented on the world map.

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)

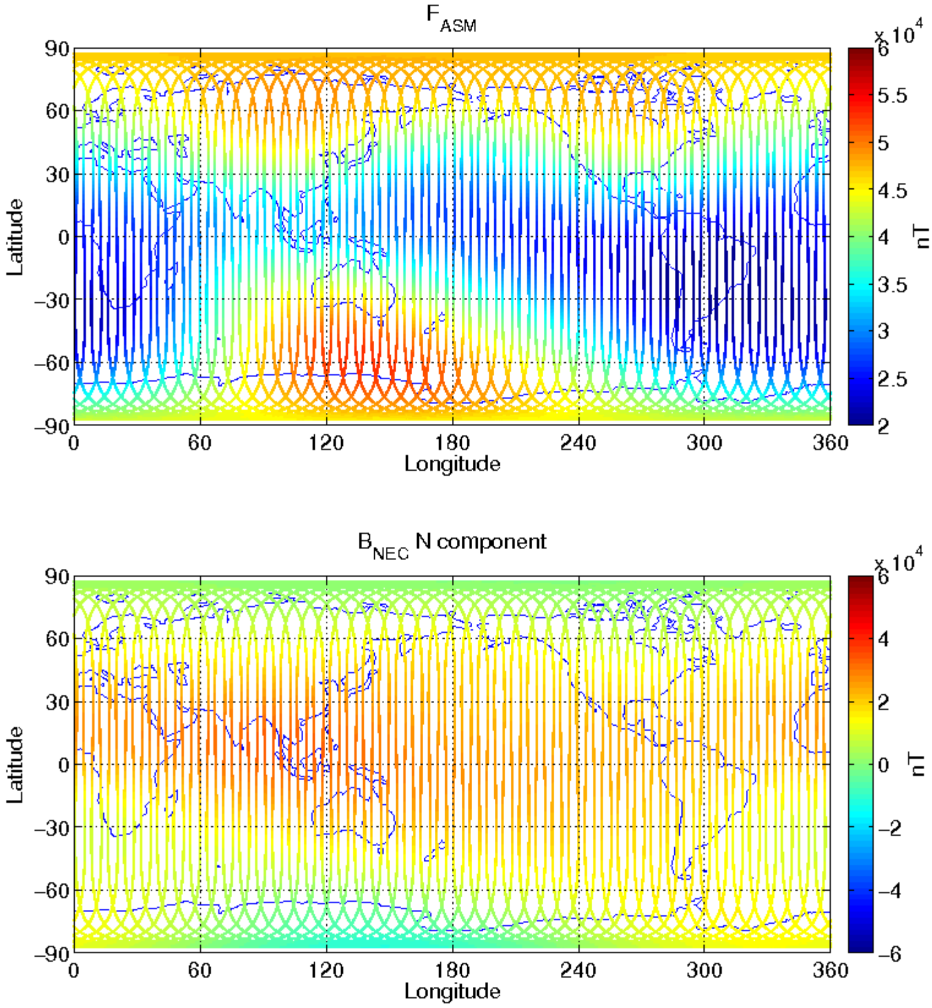
The VFM instrument parameters important for monitoring the instrument health are the VFM sensor temperatures: T_CDC, T_CSC and T_EU.

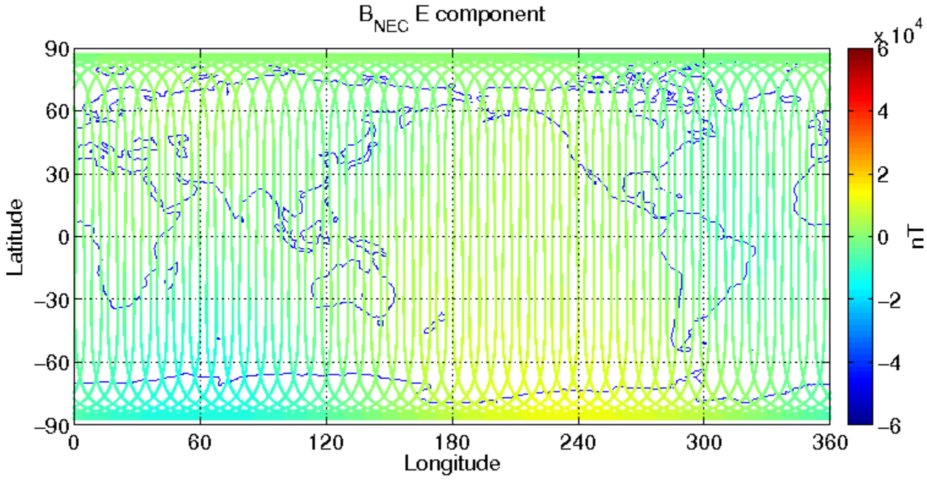
For S/C A, B and C, for reported period, the temperatures behaved as expected.

3.3.4 Magnetic time series visual inspection

3.3.4.1 Swarm A

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





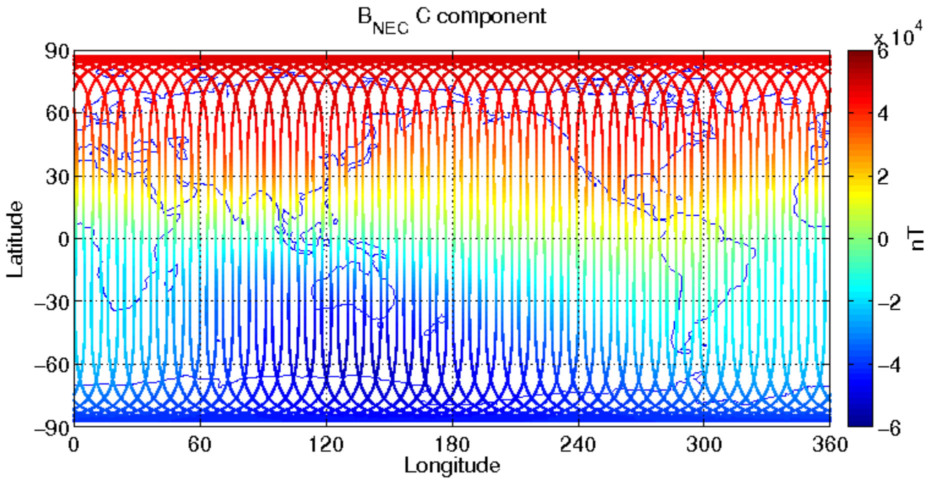
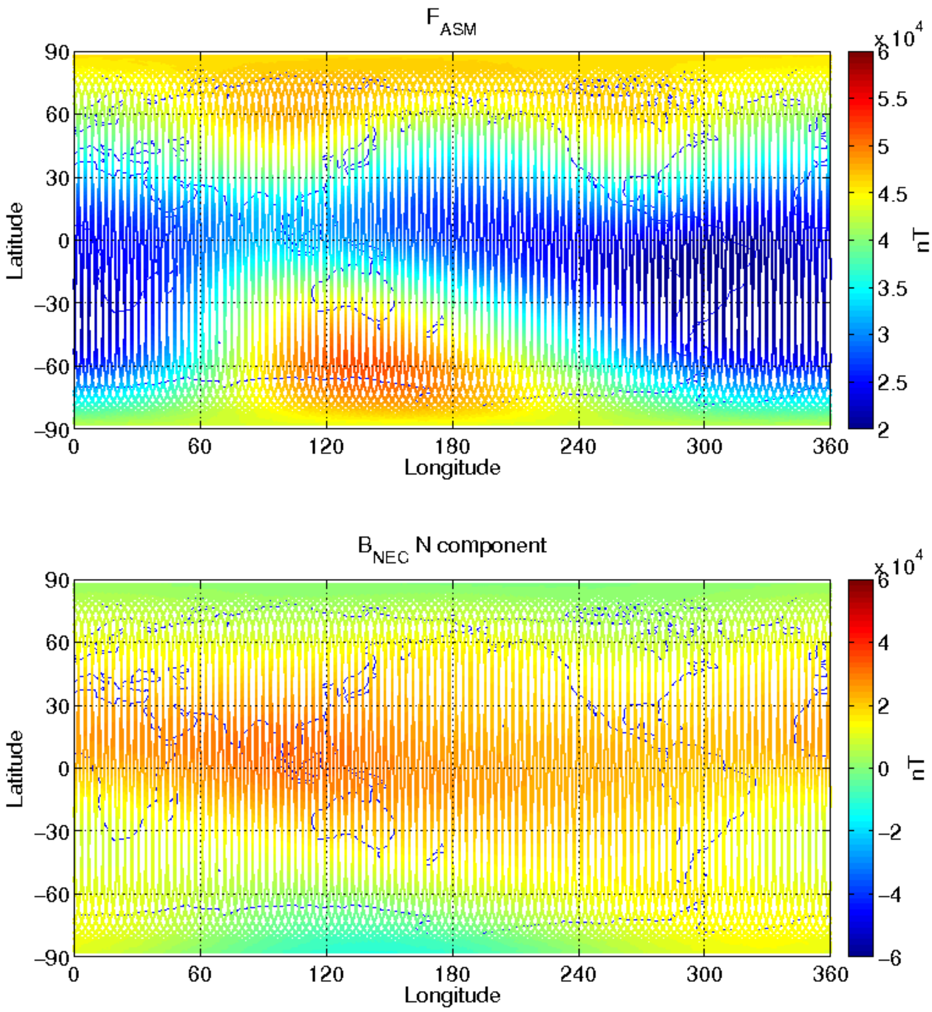
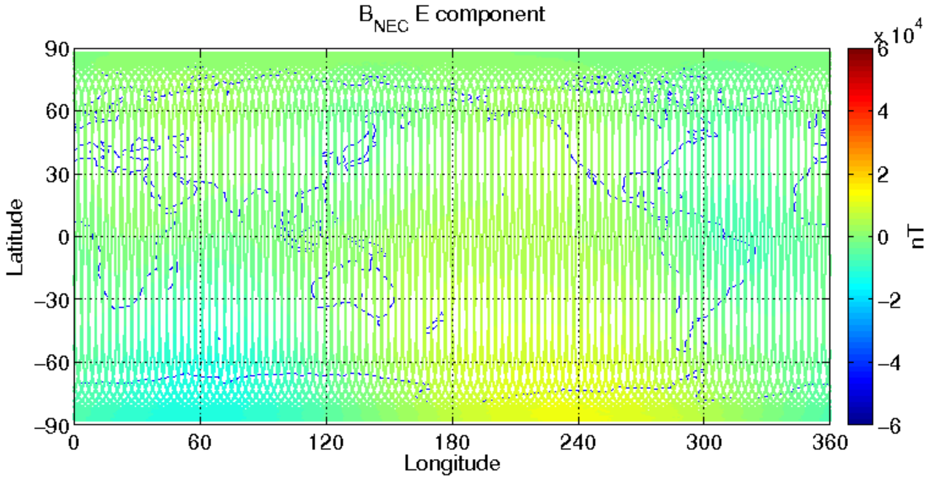


Figure 10: S/C A, world map plots of the geomagnetic field and components measured during monitoring period 07/03-13/03. From top to bottom: F-magnetic field from ASM measurement, B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement.

3.3.4.2 Swarm B

Map plots of magnetic field measurement for week 10 for S/C B can be seen in Figure 11 below.





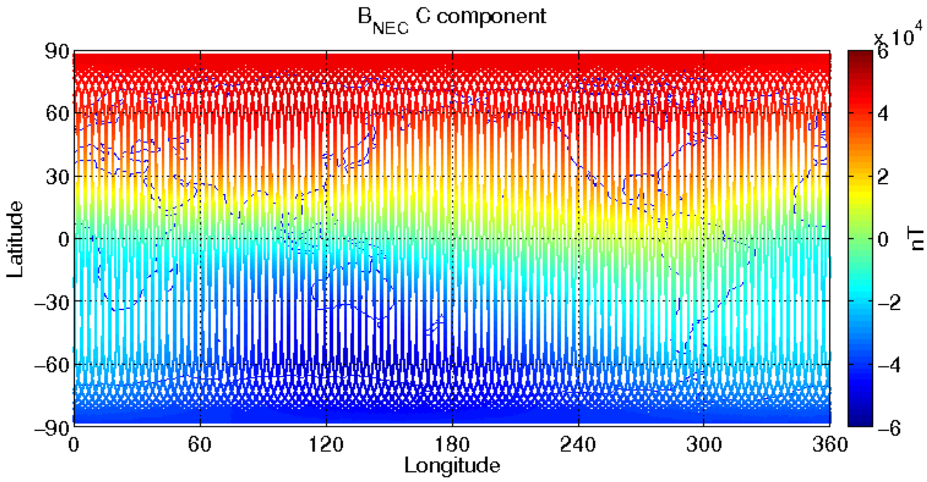


Figure 11: S/C B, world map plots of the geomagnetic field and components measured during monitoring period 07/03-13/03. From top to bottom: F-magnetic field from ASM measurement, B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement.

3.3.4.3 Swarm C

Map plots of magnetic field measurement for week 10 for S/C C can be seen in Figure 12.

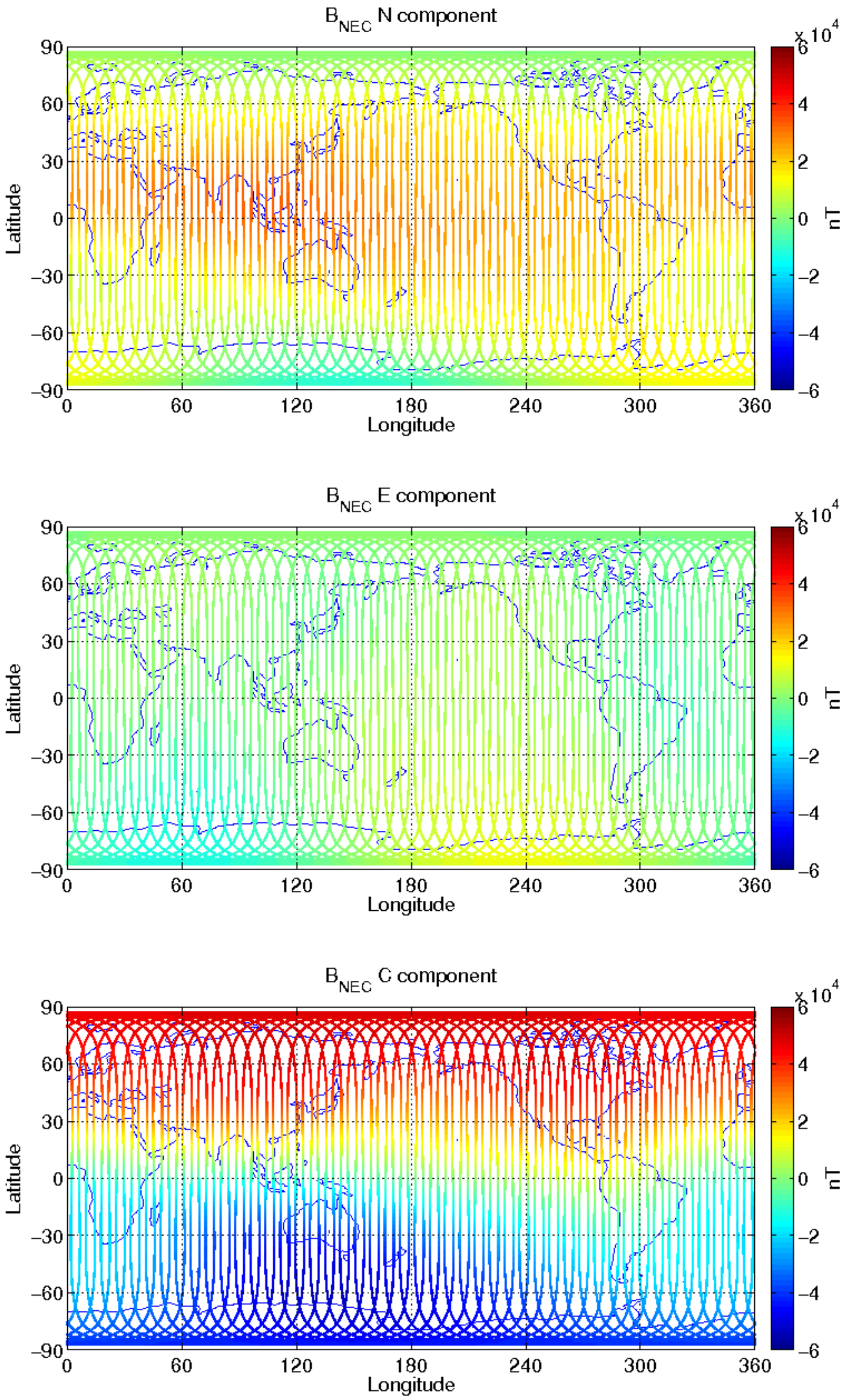


Figure 12: S/C C, world map plots of the geomagnetic field and components measured during monitoring period 07/03-13/03. From top to bottom: B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement.

3.3.5 B_{NEC} vs Chaos5 model residuals

The magnetic field measurement is compared to magnetic field estimation calculate from Crustal and Core contributions of model Chaos5. 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) Bθ and 3) Bφ.

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 07/03 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

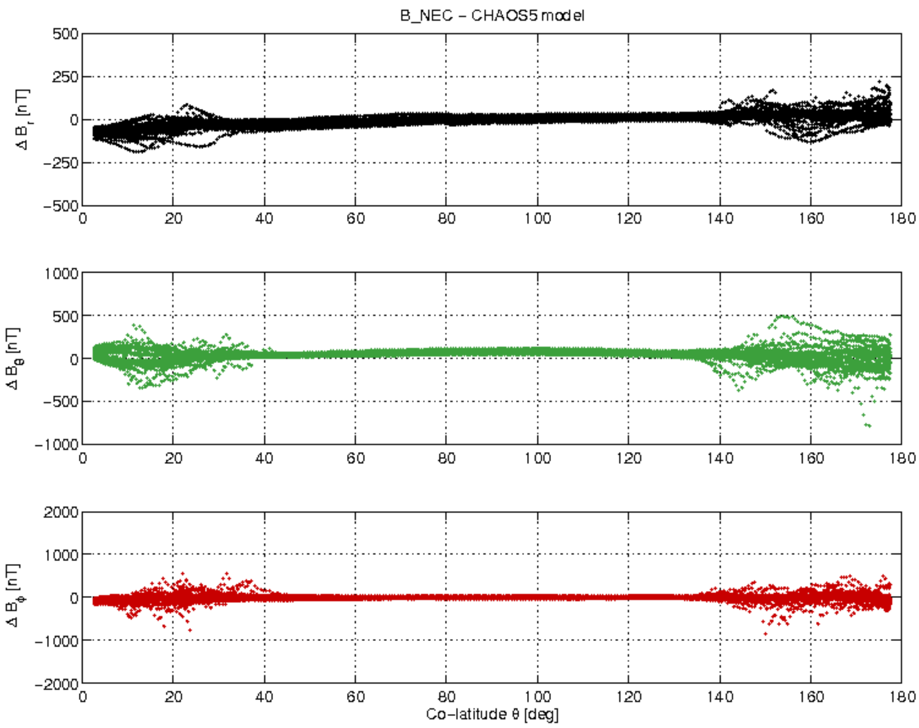


Figure 13: S/C A day 07/03 B_{NEC} - B_{Chaos} vs colatitude.

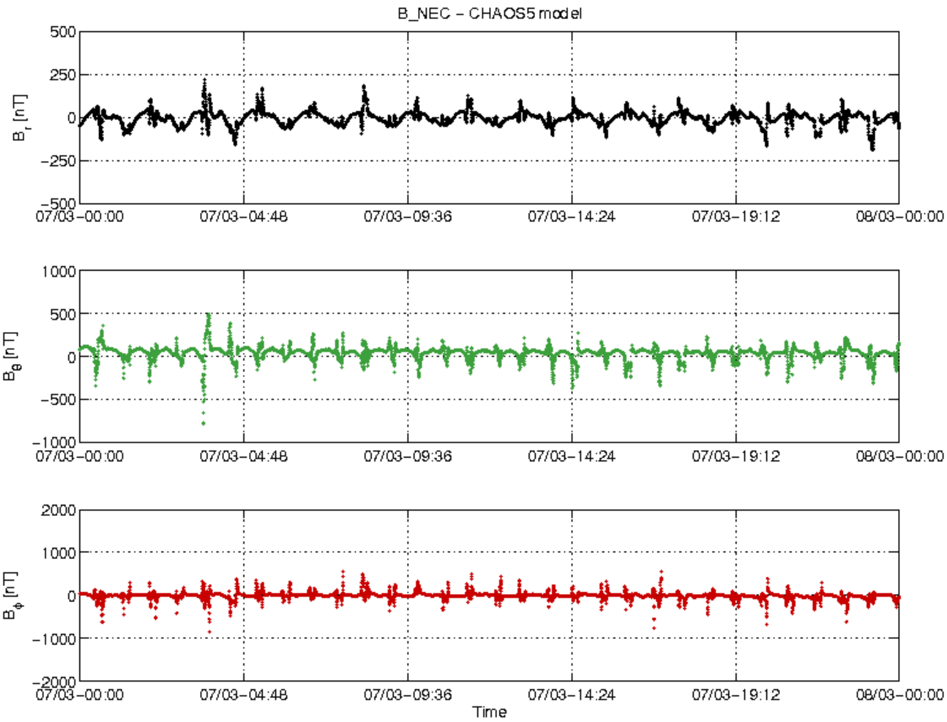


Figure 14: S/C A day 07/03: time series of $B_{NEC} – B_{Chaos}$ residuals.

3.3.5.2 Swarm B

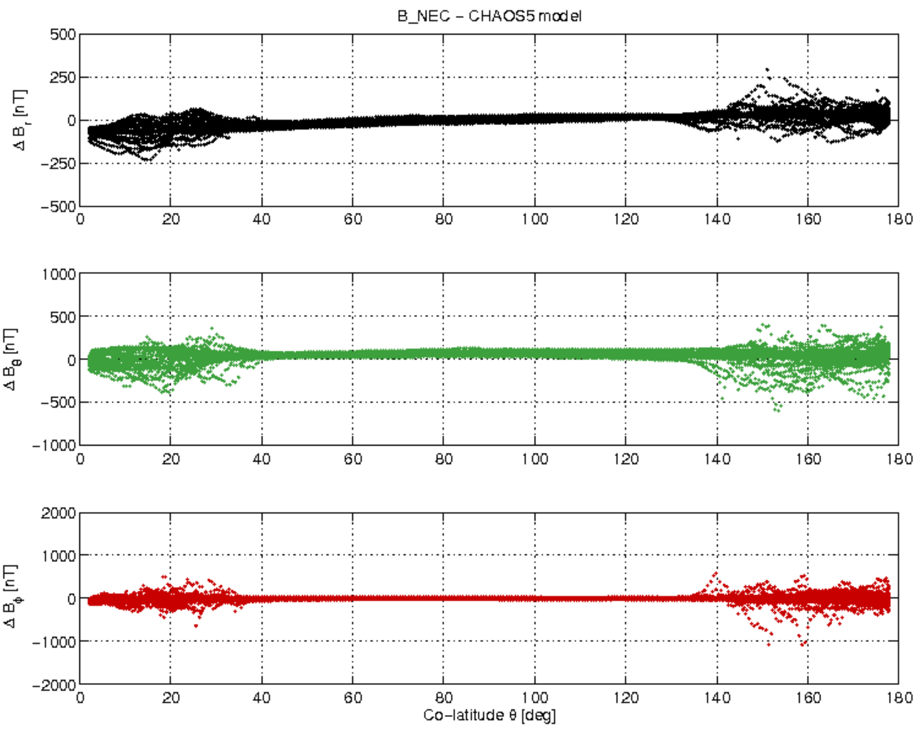


Figure 15: S/C B day 07/03 B_{NEC} - B_{Chaos} difference vs colatitude.

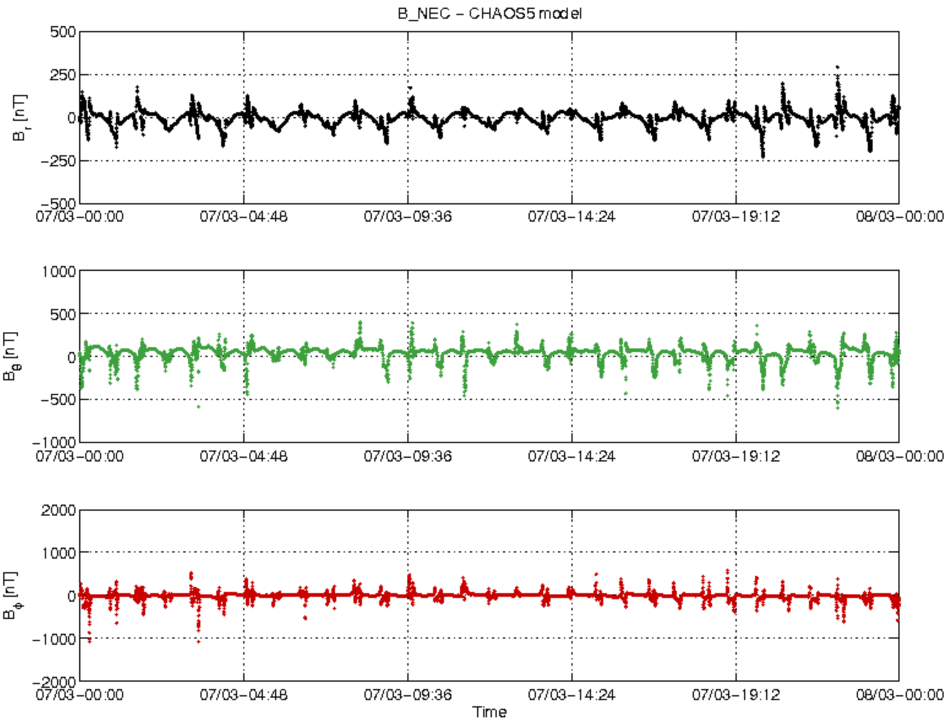


Figure 16: S/C B day 07/03 time series of $B_{NEC} – B_{Chaos}$ residuals.

3.3.5.3 Swarm C

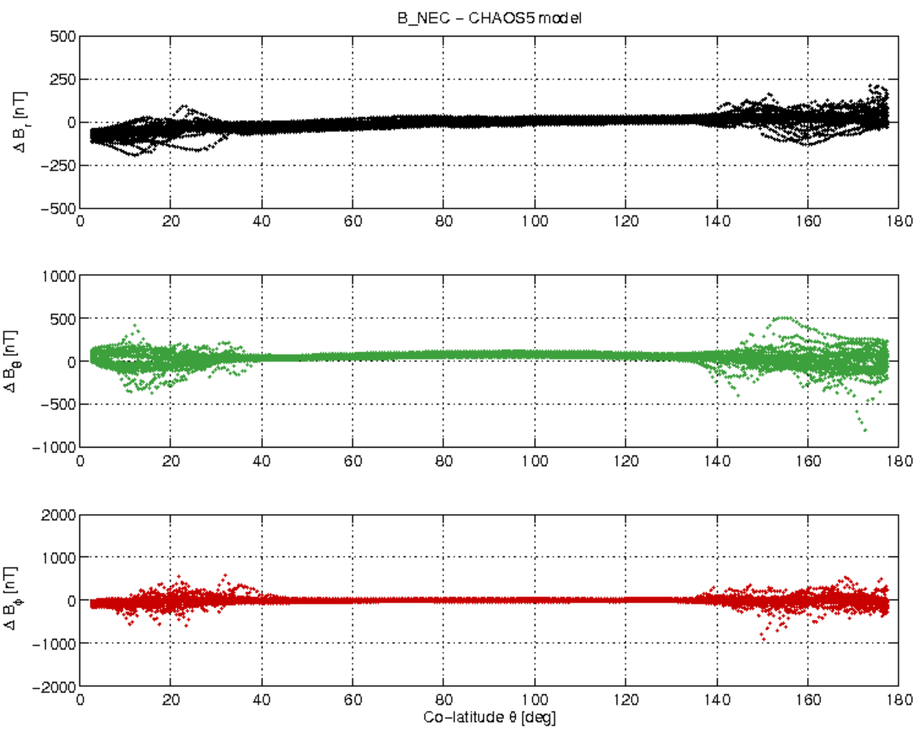


Figure 17: S/C C day 07/03 B_{NEC} - B_{Chaos} difference vs colatitude.

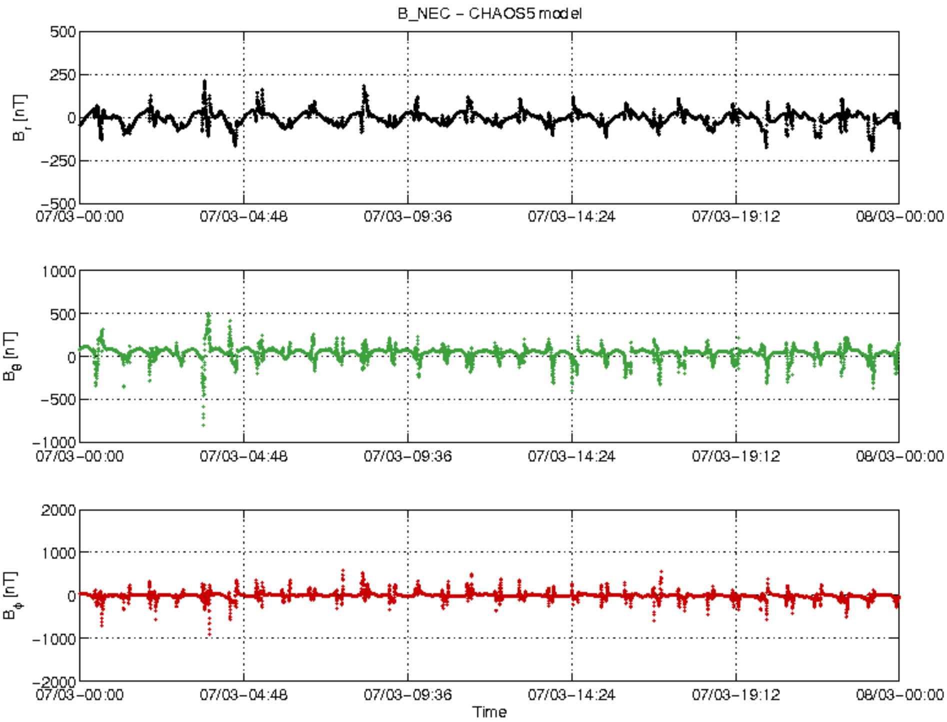


Figure 18: S/C C day 07/03 time series of $B_{NEC} – B_{Chaos}$ residuals.

4. ON-DEMAND ANALYSIS

4.1 Analysis of the second derivative of B_{NEC} and B_{VFM} (50 Hz)

The second derivative of magnetic field components has been computed using the 50Hz data (MAGx_HR_1B) from 01/02/2016 to 12/03/2016. For each spacecraft, the following analysis has been performed:

- The second difference of each component is calculated.
- The second derivative of all the data points with |Latitude| > 10° latitude is set to zero. For such modified data daily standard deviation is calculated.

In Figure 19, Figure 20 and Figure 21 the daily standard deviation of each component second derivative as a function of time (please note that Y axes is in logarithmic scale) is plotted. For all the three S/C this trend remains stable for most of the reported period, i.e., within 25-35nT/s^2.

Looking only for the 25-35nT/s2 range it can be observed that:

- Standard deviation of B'' (both in VFM and NEC frame) for S/C A stays within range 25-31nT/s^2;
- Standard deviation of B'' (both in VFM and NEC frame) for S/C B stays within range 27-33nT/s^2;
- Standard deviation of B'' (both in VFM and NEC frame) for S/C C is most stable and stays within range 26-29nT/s^2;

From these plots, it can be noticed that the East component of $B_{NEC\ i}$s the most disturbed one.

While in Figure 22, Figure 23 and Figure 24 the second derivative of the vector components (in VFM (left) and NEC (right) frame), for the day 3rd of March, for each spacecraft, are shown. In the Alpha and Charlie plots one prominent spike can be observed when analysing the vector components in NEC frame. A zoom on this spike can be seen in Figure 25 and in Figure 26 for S/C Alpha and Charlie respectively.

To be noticed that this anomalous behaviour is present only in magnetic components in NEC frame (B_{NEC}), while there is no evidence of such behaviour in magnetic components in VFM frame (B_{VFM}). Our hypothesis is that this anomaly could be caused by an issue in the quaternions interpolation from 1Hz to 50Hz data.

Indeed, if we look at the trend of the quaternions from 07:14:50 to 07:14:51, we notice a change in sign of all quaternions, and three of them (q1, q2, and q4) are very close to zero (Figure 27). If we zoom on these three quaternions, i.e. q1, q2 and q4, we see that q2 and q4 seem not to be correctly calculated (Figure 28).

Further investigation will be performed to verify this hypothesis.

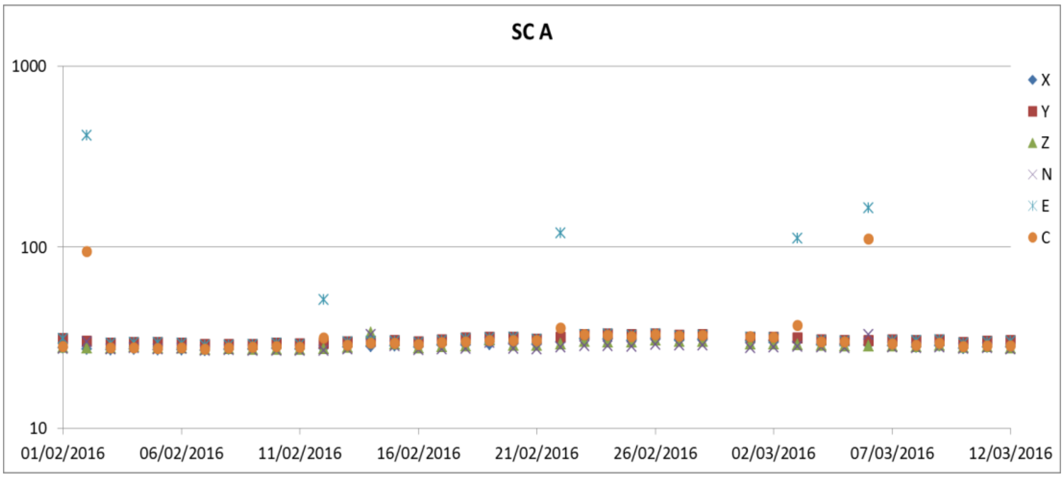


Figure 19: S/C A, daily standard deviation of each component second derivative as a function of time (please note logarithmic vertical scale).

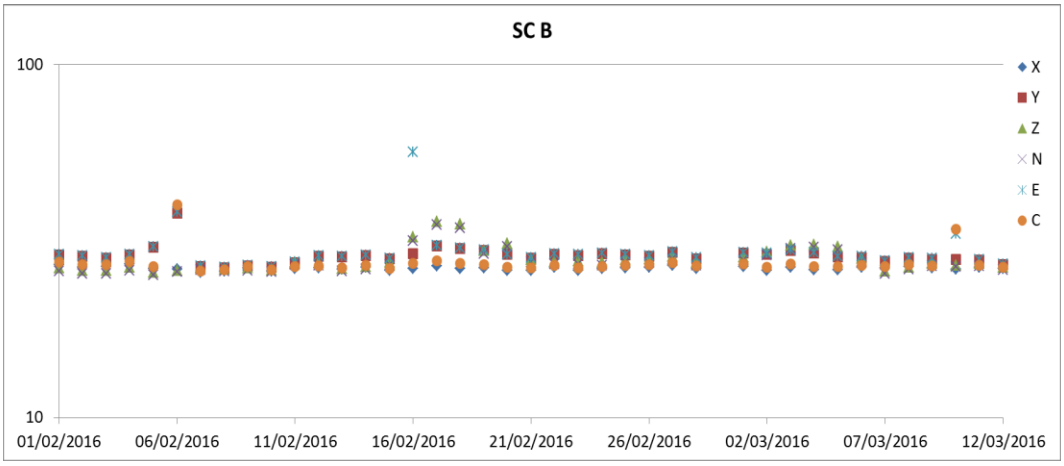


Figure 20: S/C B, daily standard deviation of each component second derivative as a function of time (please note logarithmic vertical scale).

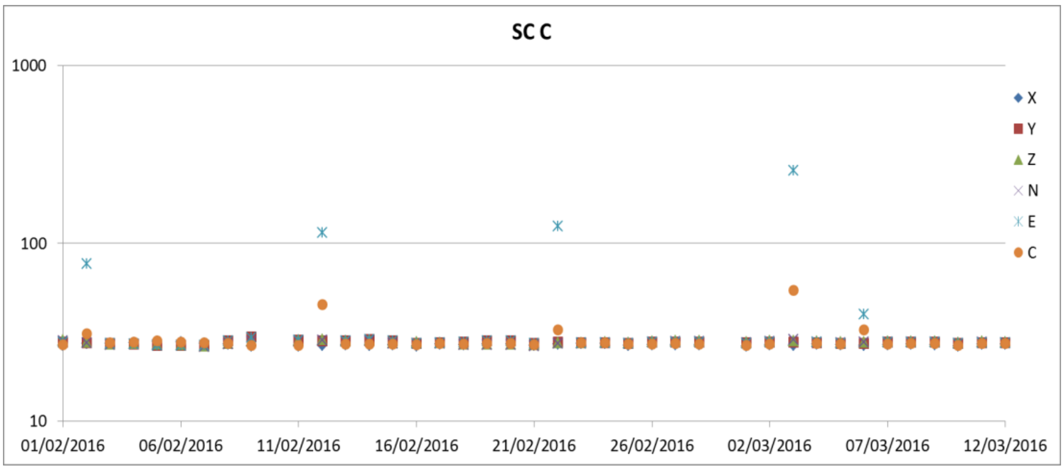


Figure 21: S/C C, daily standard deviation of each component second derivative as a function of time (please note logarithmic vertical scale).

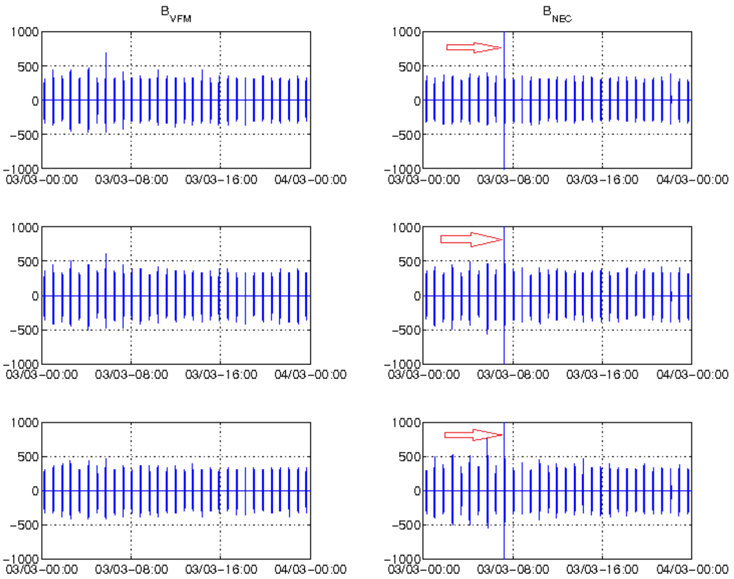


Figure 22: S/C A, plot of second derivative of magnetic field components. In left column plotted $B_{VFM,}$ from top to bottom X, Y, and Z component. Right column plotted B_{NEC}, from top to bottom North, East and Centre component.

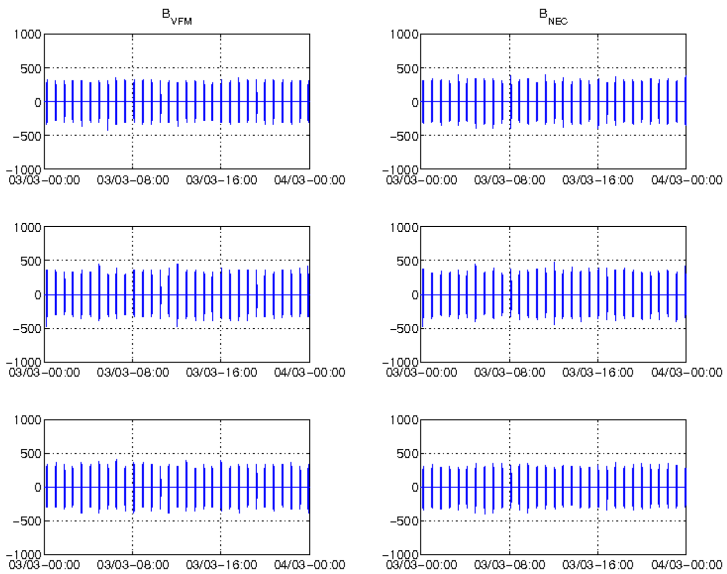


Figure 23: S/C B, plot of second derivative of magnetic field components. In left column plotted $B_{VFM,}$ from top to bottom X, Y, and Z component. Right column plotted B_{NEC}, from top to bottom North, East and Centre component.

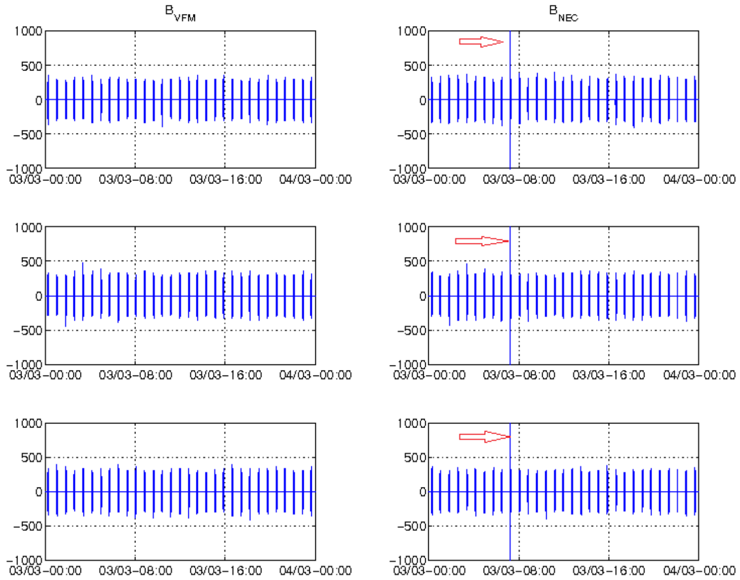


Figure 24: S/C C, plot of second derivative of magnetic field components. In left column plotted $B_{VFM,}$ from top to bottom X, Y, and Z component. Right column plotted B_{NEC}, from top to bottom North, East and Centre component.

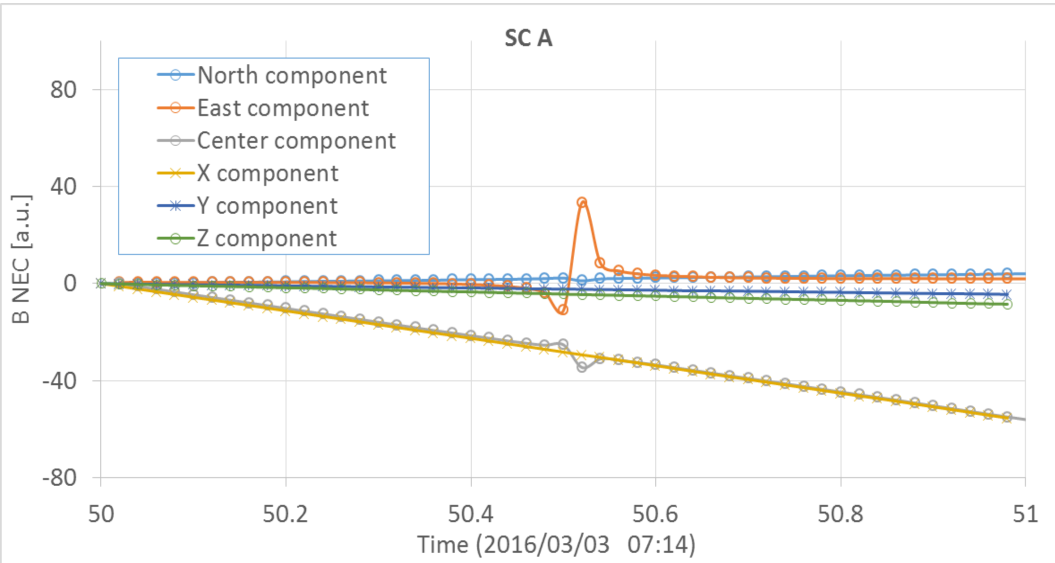


Figure 25: Plot of magnetic field components rescaled in order to have zero value at 7:14:50.00. There exist one noticeable spike in East and Centre components, and a small bump in North component.

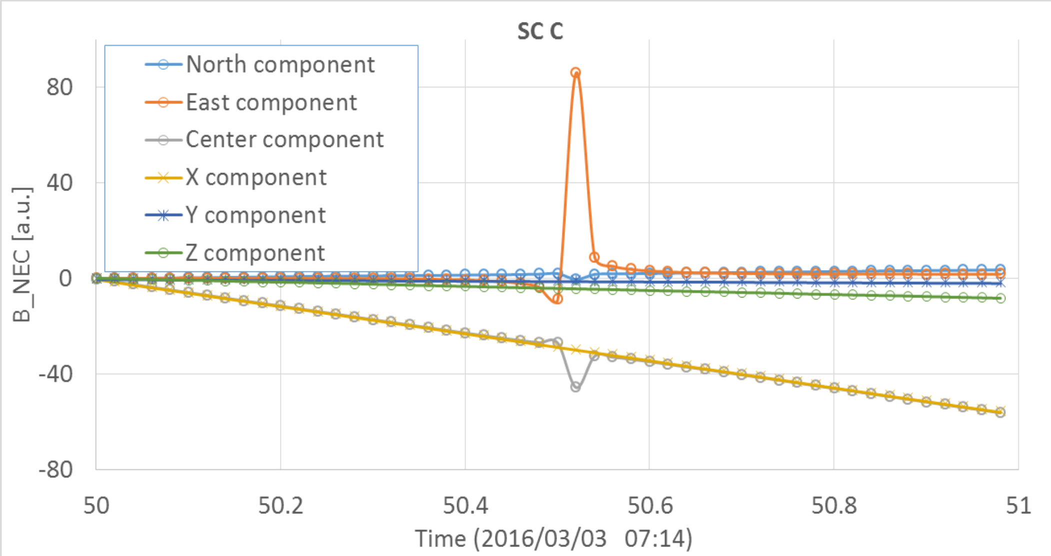


Figure 26:: Plot of magnetic field components rescaled in order to have zero value at 7:14:50.00. There exist one noticeable spike in East and Centre components, and a small bump in North component.

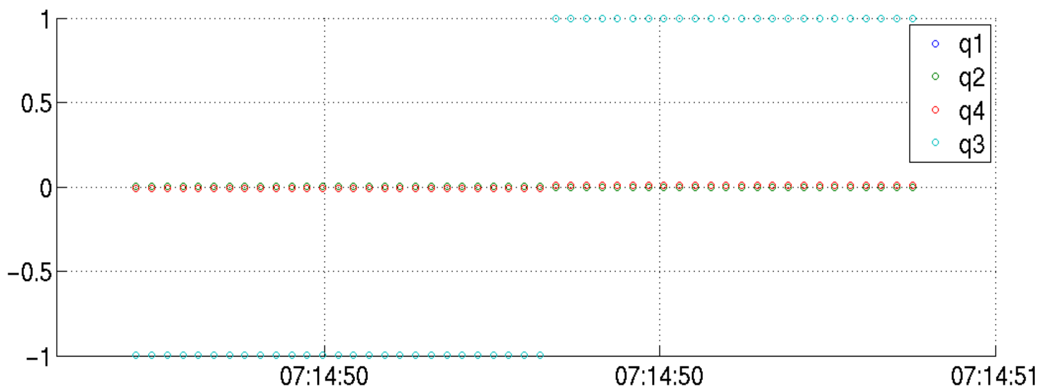


Figure 27: Plot of quaternions at the time of the spike of magnetic field in NEC frame.

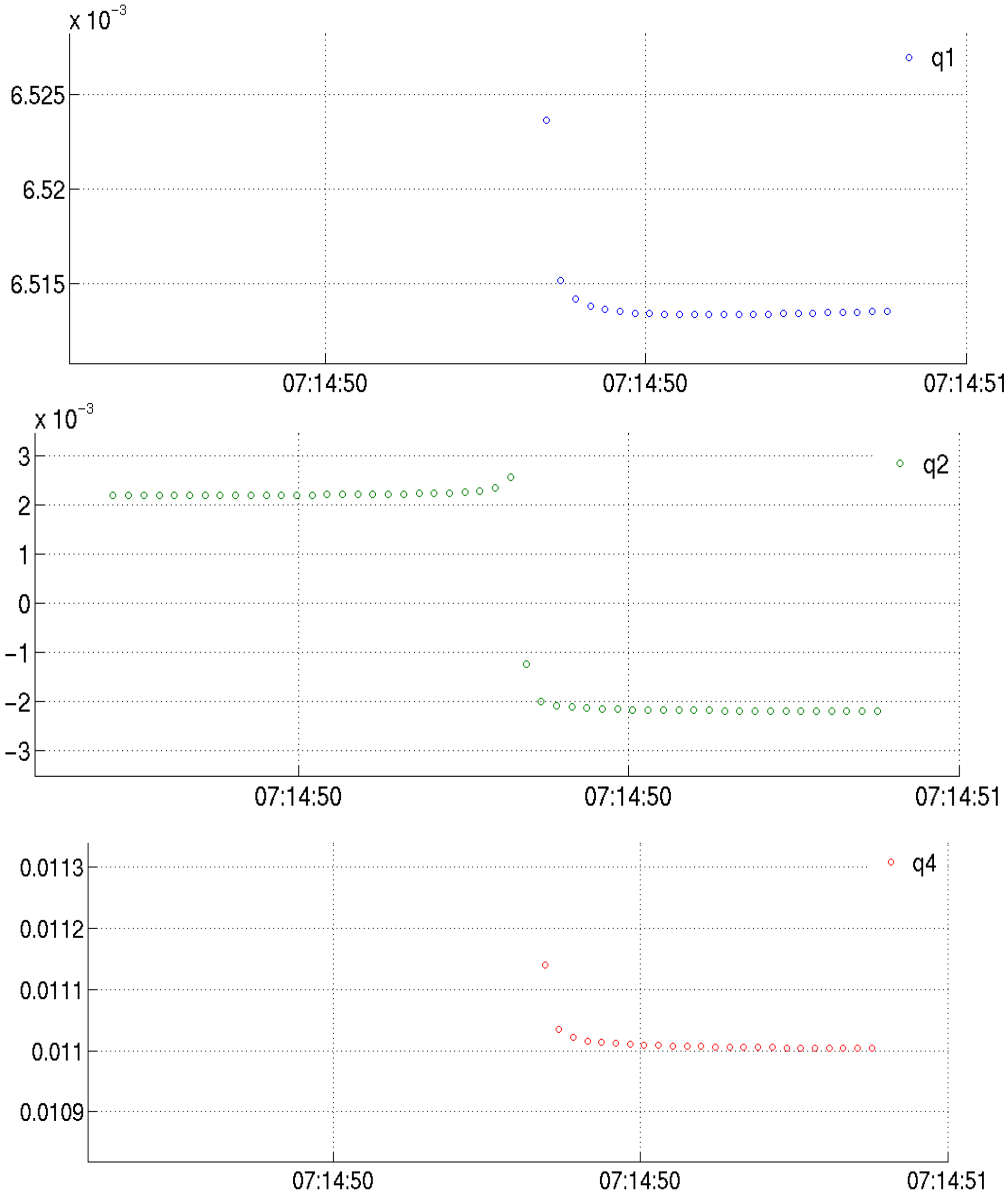


Figure 28: Zoom on q1, q2 and q4 quaternions at the time of the spike. Quaternion 2 and 4 seem to be not correctly calculated.

End of Document