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IDEAS+ Swarm Weekly Report 2015/47: 2015/11/16 - 2015/11/22

Abstract : This is the **Instrument Data quality Evaluation and Analysis Service Plus** (IDEAS+) Swarm Weekly report on Swarm products quality, covering the period from 16 November to 22 November 2015.

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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	07 Dec 2015	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.p3.
- 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 0007 (29/10/2015), 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

A new delivery of the L1BOP is foreseen for end 2015/beginning 2016 in order to cope with the following issues:

1. RINEX correction due to a better alignment of the Instrument Measurement Time,
2. Fixing ORBATT bugs (related to Leap second handling and SPRs SWL1L2DB-75 and 84, see Sect. 2.4 for a more detailed description)
3. Separating the time dependent calibration corrections and the external disturbance effects in the VFM data: introduction of "s_beta" (scale factor depending on elevation angle Beta) and "s_exp" ("aging" scale factor modelled as an exponential function) in the scale calibration.
4. Possibly, a correction in the conversion from Level 0s into Level 1B of the Langmuir Probe offset parameters.

A new delivery of the Level 2 – Cat 2 EEF processor expected by January 2016 in order to be able to produce EEF data also for Swarm C after the ASM stop.

2.3 Quality Working Group and Cal/Val Coordination

Following the decisions of the 5th QWG in Paris, these activities will be carried on in order to better understand the origin of the ASM-VFM residuals:

- Investigation on boom alignment error budget (from industry) that could help in developing a thermos-elastic correction approach.

- Investigation on plasma-induced stray field in order to focus on any possible current flow near the VFM (and not the ASM), because the intensity of such a current may be stronger near the VFM due to the accumulation of charged plasma particles near the STR baffles.

In the meantime, DTU will deliver an ASM-VFM residual dataset to be distributed to all the Swarm users through the ESA FTP server (/Advanced folder).

Following the decisions of the 5th QWG in Paris, University of Calgary has delivered to the benefit of expert users through the ESA FTP server (/Advanced folder), the 16 Hz TII raw image moments for selected periods during 2013 and 2014 for all S/C.

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

- 16 Hz Faceplate currents and derived electron density (by end November)
- Single-probe derived electron temperatures and S/C potential (by end November)
- Sweep mode derived electron density and temperature and S/C potential (by end December).

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 2015, Week 47 (16/11 - 22/11)

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

- **No data generated for 20/11 due to failure of ORBATT processor** (SWL1L2DB-84); the failure occurred in similar conditions as for another ORBATT-B failure on 27/7 (SWL1L2DB-75). The processor manufacturer has already found the root cause of the failures: some gaps in the telemetry led to re-dumps and consequent segmentation of the input Level 0s. Because of a bug, when a loop is done over one particular variable ("L0headers"), and inside the loop a different variable is accessed ("STRL0headers"), if these two variables have the same size then the problem does not occur, but when "L0headers" is bigger than "STRL0headers" a segmentation fault is produced. The fix has been already implemented in the manufacturer testbed, and a new delivery of L1BOP is expected including, among other things, this fix too.

- **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 2015, Week 47: 16/11 - 22/11.

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

The relevant parameters that have been monitored are:

- Position difference between calculated Medium Accuracy orbits (**MODx_SC_1B**) and on-board solution (**GPSxNAV_0**). Threshold values for such differences have not been assessed yet: we have just monitored the average values and maximum variations around the week. They are reported in tables in the sections below. In addition, some example plots are given from the HTML daily reports. For the time being we evaluated an anomaly should be raised if one (or more) of the following conditions occurs:

  o The **average difference** on a given day exceeds the position accuracy requirement for the mission (1.5 m),

  o The variability around the average is quite high: **standard deviation** threshold has been arbitrarily chosen to be twice the position accuracy requirement for the mission (2-sigma = 3 m).

  o At least 4-5 spikes are observed on a given day, exceeding +/- 50 m.

- Visual inspection of Star Tracker characterisation flags (**STRxATT_1B**)
- Deviation of the quaternion norm from unity (deviation threshold = +/- 10^{-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, 16/11 - 22/11, Position difference				
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
16/11	0.16	-10.5	5.9 (X)	1.44	
17/11	0.1	-8	7.8 (Y)	1.39	
18/11	0.06	-7.3	8.5	1.36	
19/11	0.04	-10.2	8.5	1.47	
20/11	0.07	-7.7	6.2	1.42	
21/11	0.04	-6.2	9.9	1.39	
22/11	0.09	-6.8	7.2	1.24	
Swarm B, 16/11 - 22/11, Position difference				
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
16/11	0.06	-6.6	6.7	1.43	
17/11	0.08	-6.8	6	1.34	
18/11	0.13	-7.7	5.2	1.33	
19/11	0.12	-6.1	6.3	1.41	
20/11	Data not avail.	Data not avail.	Data not avail.	Data not avail.	See 2.2
21/11	0.1	-8.8	7.3	1.33	
22/11	0.05	-6.2	7.4	1.26	
Swarm C, 16/11 - 22/11, Position difference				
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
16/11	0.1	-8.8	7.7	1.45	
17/11	0.07	-6.9	8.4	1.39	
18/11	0.08	-7.5	8.1	1.36	
19/11	0.06	-7 (Y)	7.9 (X)	1.43	
20/11	0.09	-9.3	7.7	1.41	
21/11	0.03	-6.1	10.1	1.35	
22/11	0.11	-6.5	6.1	1.22	
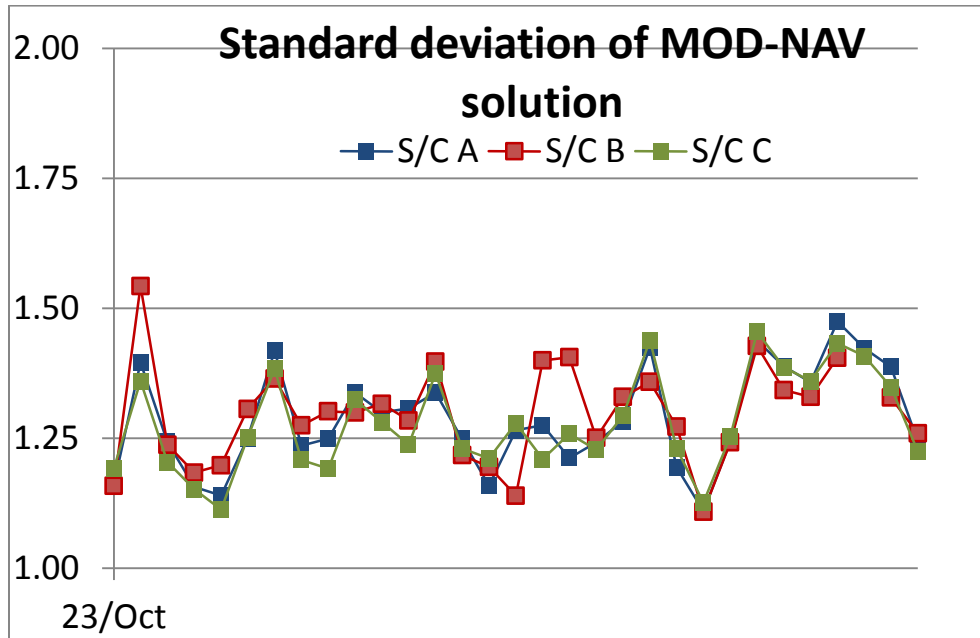
Figure 1 Plot of the standard deviation of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.
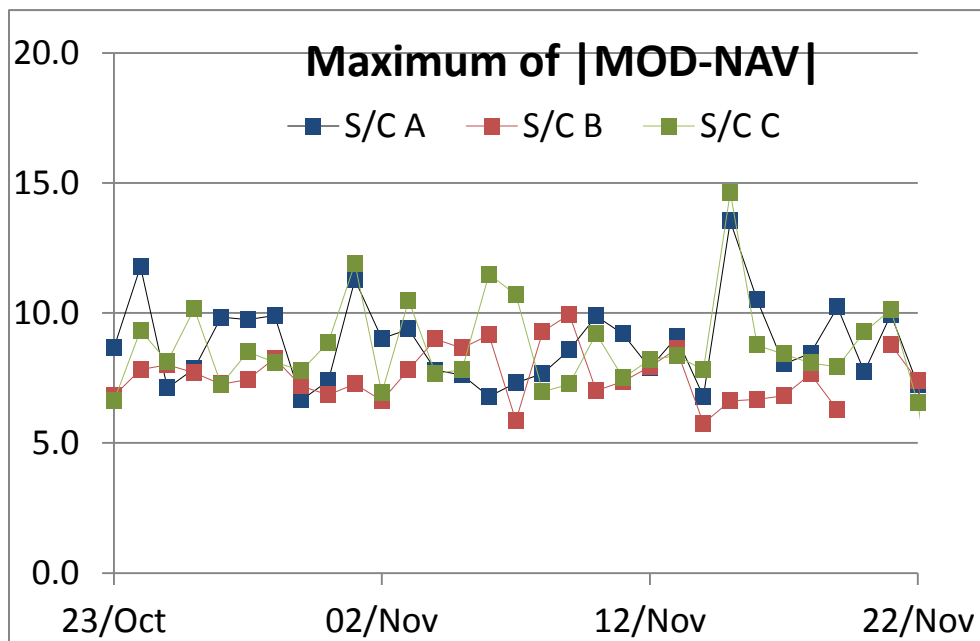

Figure 2 Plot of the maximum difference of the absolute value of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.

3.2.1.1   Swarm A

Below some plot example follows of MOD-NAV differences, S/C A, taken at the beginning of the week (16/11, 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].
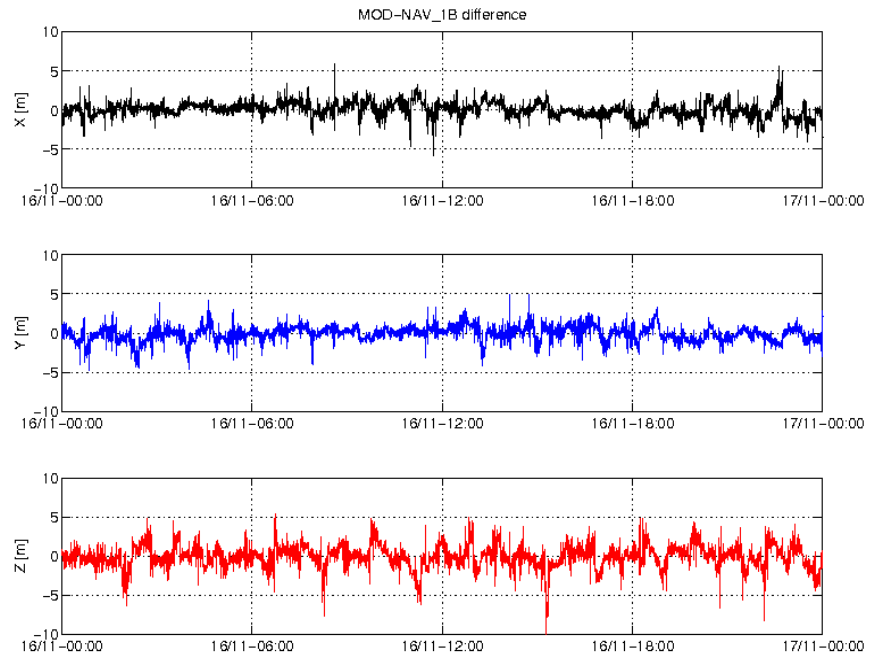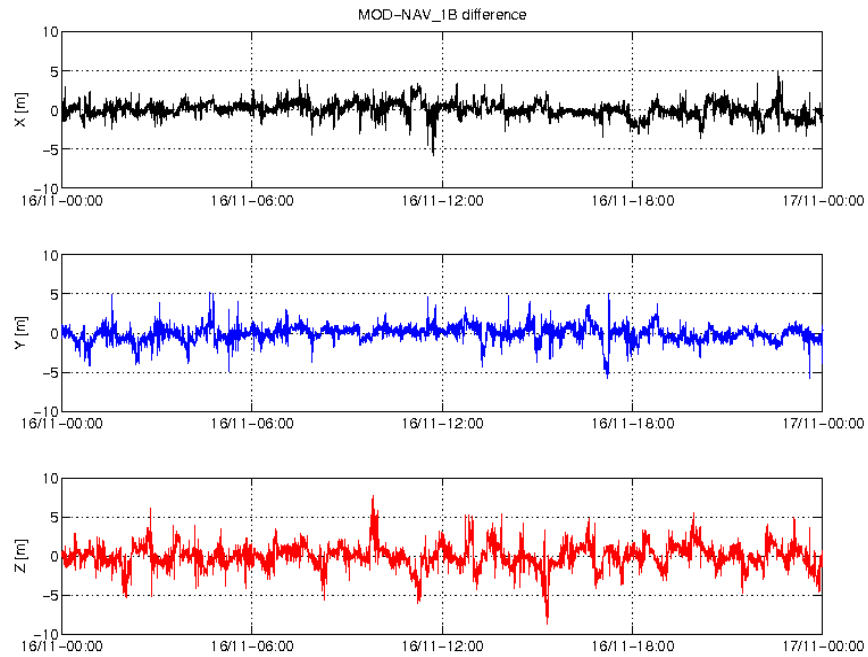
Figure 3: Difference MOD-GPSNAV, S/C A, 16/11. From top to bottom: X, Y and Z-axis

3.2.1.2   Swarm B

Below some plot example follows of MOD-NAV differences, S/C B, taken at the beginning of the week (16/11, 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].
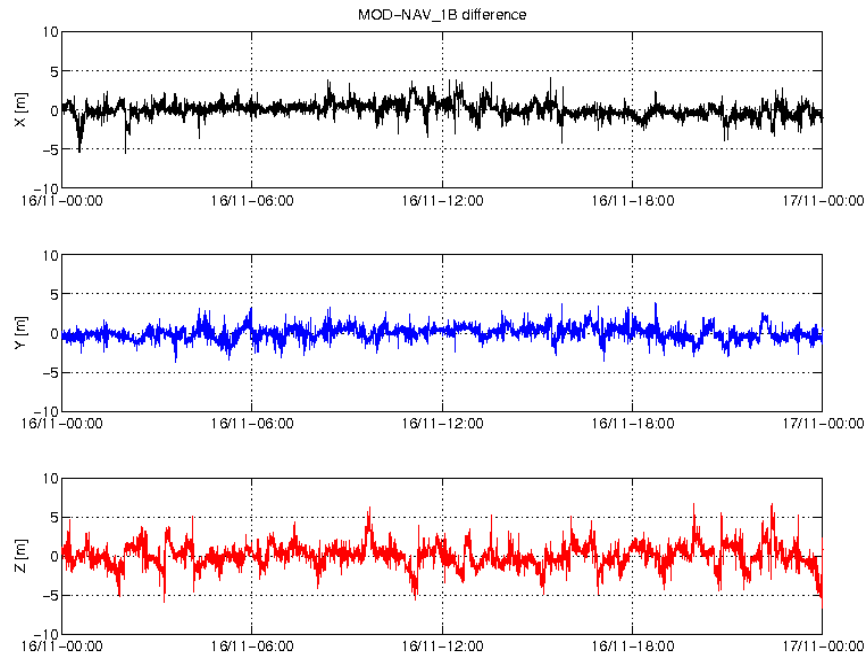
Figure 4: Difference MOD-GPSNAV, S/C B, 16/11. From top to bottom: X, Y and Z-axis

3.2.1.3   Swarm C

Below some plot example of MOD-NAV differences, S/C C, taken at the beginning of the week (16/11, 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, 16/11. 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

No data for 20/11 due to processing error.

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.

- 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.

- Comparison of magnetic data (B_{NEC}) with a model (Chaos4plus)

3.3.1 VFM-ASM anomaly

3.3.2 ASM-VFM difference statistics

In Table 3, 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 shows the daily mean (circles) and standard deviation (crosses) of dF for Swarm A and Swarm B respectively.

Table 3 Swarm A and B, difference between magnetic field absolute value measured by ASM and by VFM.

| Day	Max (nT)	Min (nT)	Standard deviation (nT)	Mean (nT)	Notes
Swarm A, 16/11 - 22/11, ASM-VFM difference					
16/11	0.88	-0.76	0.29	0.04	
17/11	0.8	-0.76	0.28	0.04	
18/11	0.53	-0.67	0.24	0.02	
19/11	0.63	-0.71	0.27	0.03	
20/11	0.57	-0.64	0.23	0.04	
21/11	0.61	-0.55	0.22	0.06	
22/11	0.62	-0.63	0.22	0.07	
Swarm B, 16/11 - 22/11, ASM-VFM difference					
Day	Max (nT)	Min (nT)	Standard deviation (nT)	Mean (nT)	Notes
16/11	0.71	-0.72	0.29	0.002	
17/11	0.71	-0.75	0.28	0.003	
18/11	0.74	-0.6	0.24	0.03	
19/11	0.72	-0.65	0.26	0.04	
20/11	No data avail.	No data avail.	No data avail.	No data avail.	See 2.2
21/11	0.75	-0.52	0.23	0.07	
22/11	0.71	-0.6	0.24	0.06	
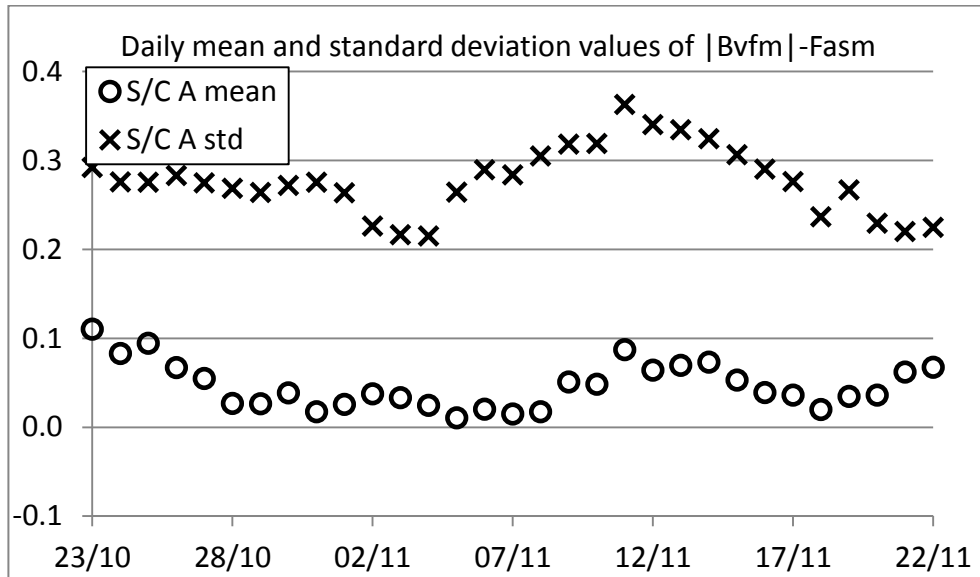
Figure 6 Daily mean and standard deviation values of ASM-VFM residuals (defined as $dF=|B_{VFM}|-F_{ASM}$) for S/C A.
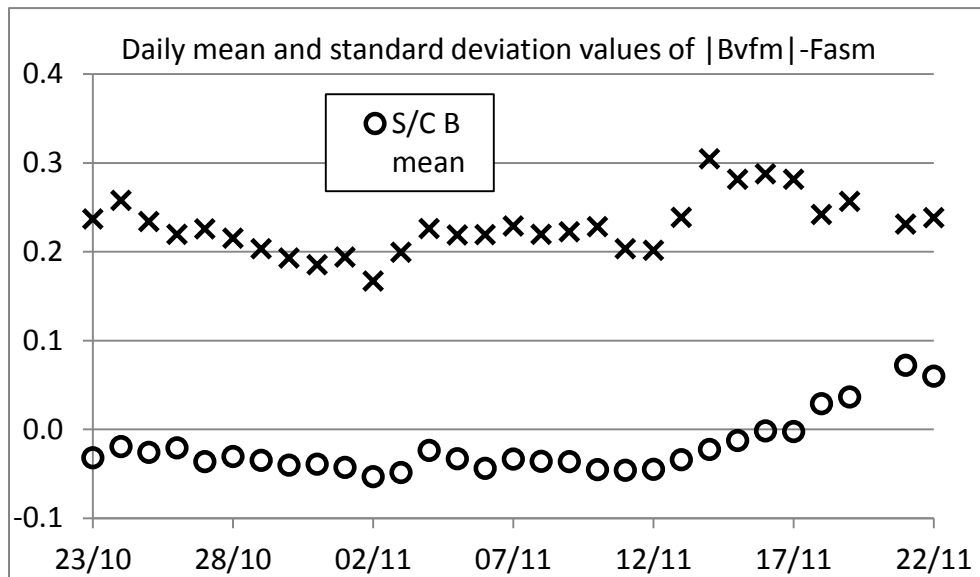

Figure 7 Daily mean and standard deviation values of ASM-VFM residuals (defined as $dF=|B_{VFM}|-F_{ASM}$) for S/C B.

3.3.2.1   Swarm A

The daily peak-to-peak difference around the week stays within [-0.75, 0.9] nT. Below two example plots of such differences for the days: 16/11 (Figure 8), and 22/11 (Figure 9).
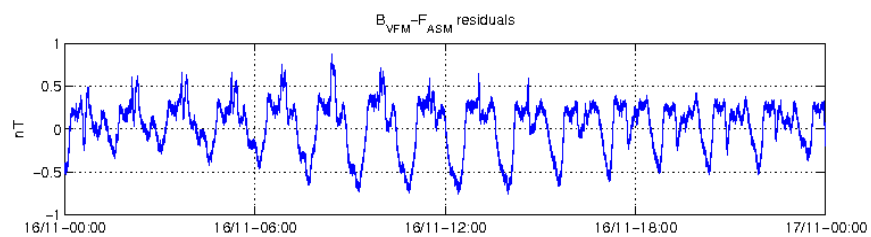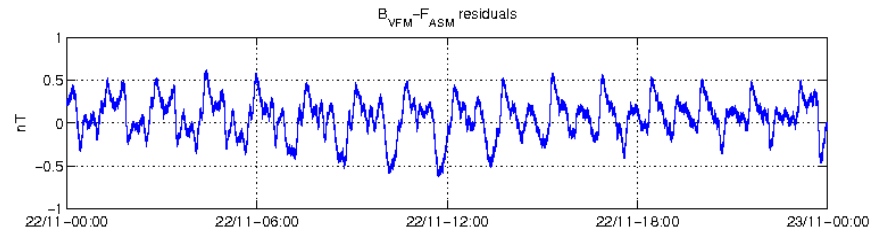

Figure 8: ASM-VFM residuals for S/C A, 16/11.

Figure 9: ASM-VFM residuals for S/C A, 22/11.

3.3.2.2   Swarm B

The daily peak-to-peak difference around the week is, on average: [-0.7, 0.7] nT. Below two example plots follows of such differences: 16/11 (Figure 10), and 22/11 (Figure 11).
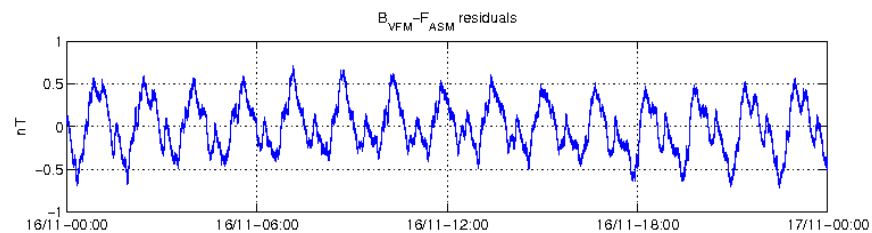
Figure 10: ASM-VFM residuals for S/C B, 16/11.
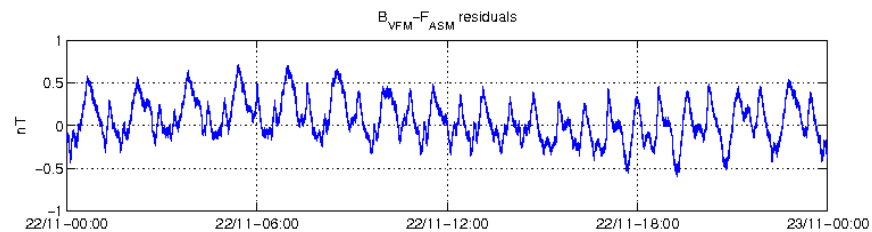
Figure 11: ASM-VFM residuals for S/C B, 22/11.

3.3.2.3   Swarm C

No data because ASM is switched off.

3.3.3 ASM Instrument parameters: quartz frequency and ASM temperature (ASMAVEC_0)

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

3.3.4 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.

3.3.5 Magnetic time series visual inspection

3.3.5.1   Swarm A

An example of representative magnetic field time series for S/C A (22/11) can be seen in Figure 12 below.
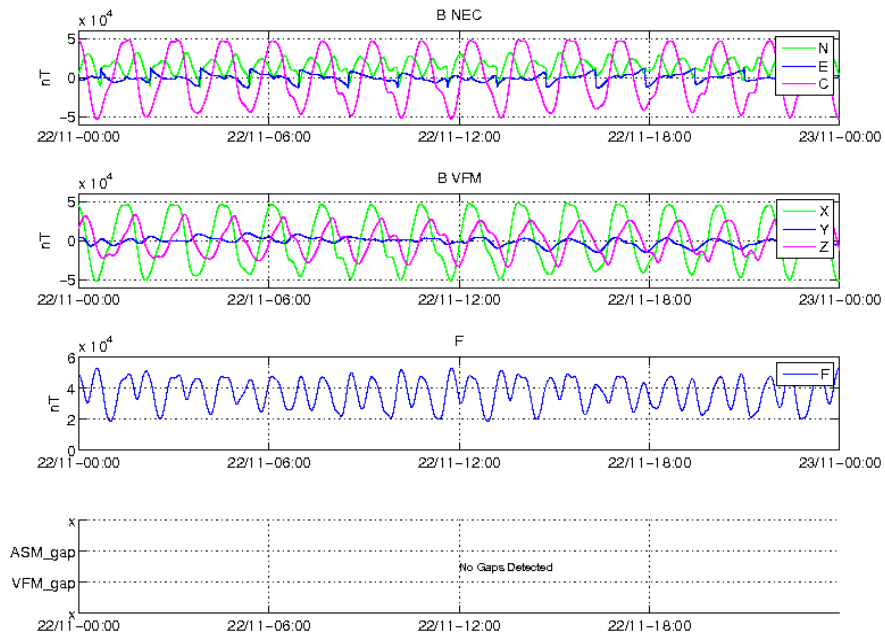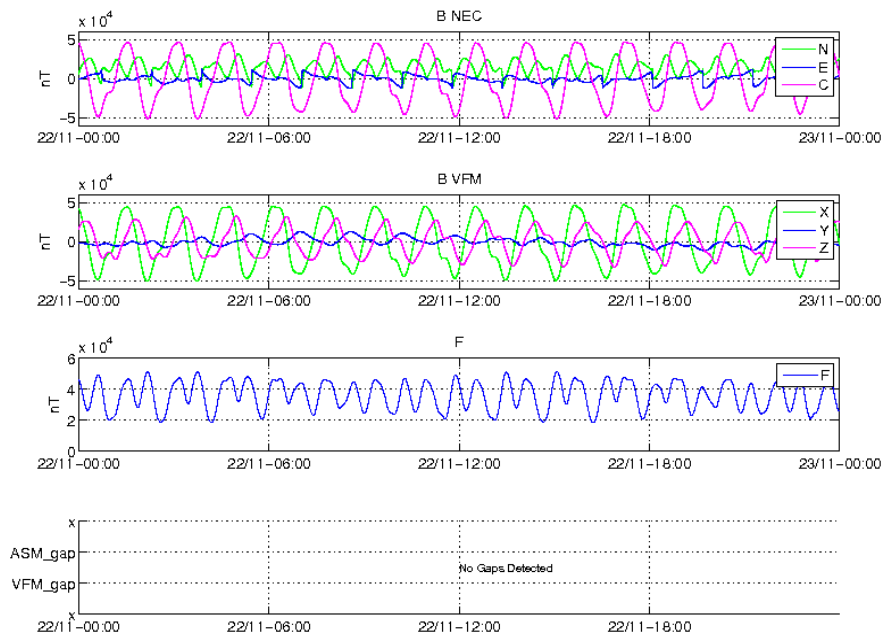

Figure 12: Time series of the geomagnetic field, for 22/11, S/C A. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM, and location of gaps (if any).

3.3.5.2   Swarm B

An example of representative magnetic field time series for S/C B (22/11) can be seen in Figure 13 below.

Figure 13: Time series of the geomagnetic field for 22/11, S/C B. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM, and location of gaps (if any).

3.3.5.3   Swarm C

An example of magnetic field time series for S/C C (22/11) can be seen in Figure 14.
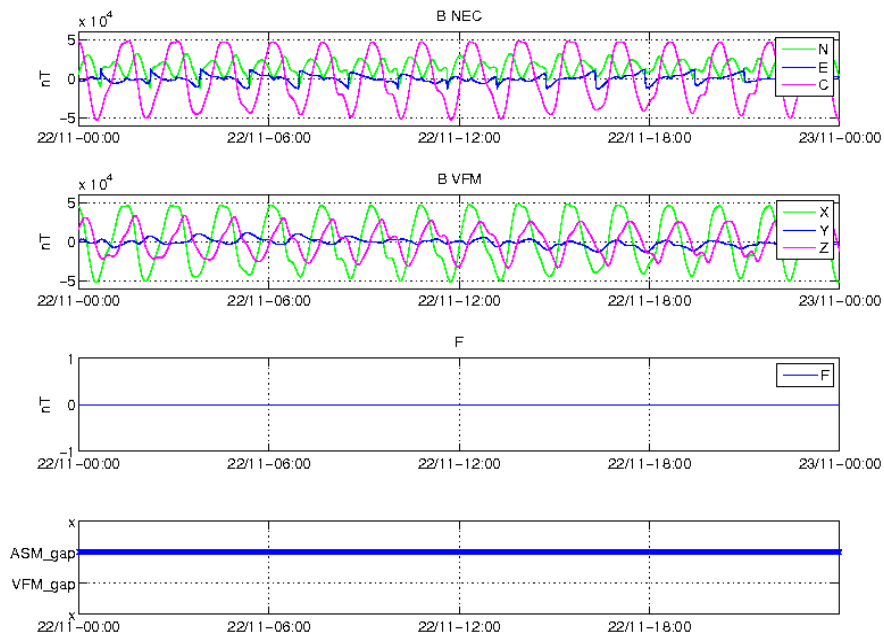
Figure 14: Time series of the geomagnetic field for 22/11, S/C C. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM (no data here because ASM it is off) and location of gaps.

3.3.6 B_{NEC} vs Chaos4plus model residuals

Figure 15, Figure 17 and Figure 19 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 16, Figure 18 and Figure 20 shows, from top to bottom, the time series on 16/11 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 Bθ_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.
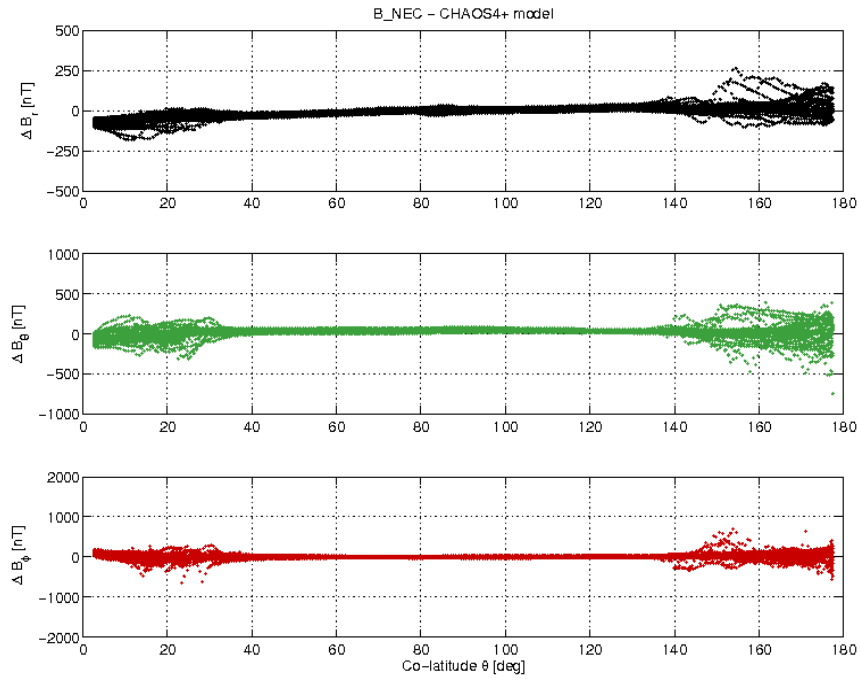
3.3.6.1 Swarm A

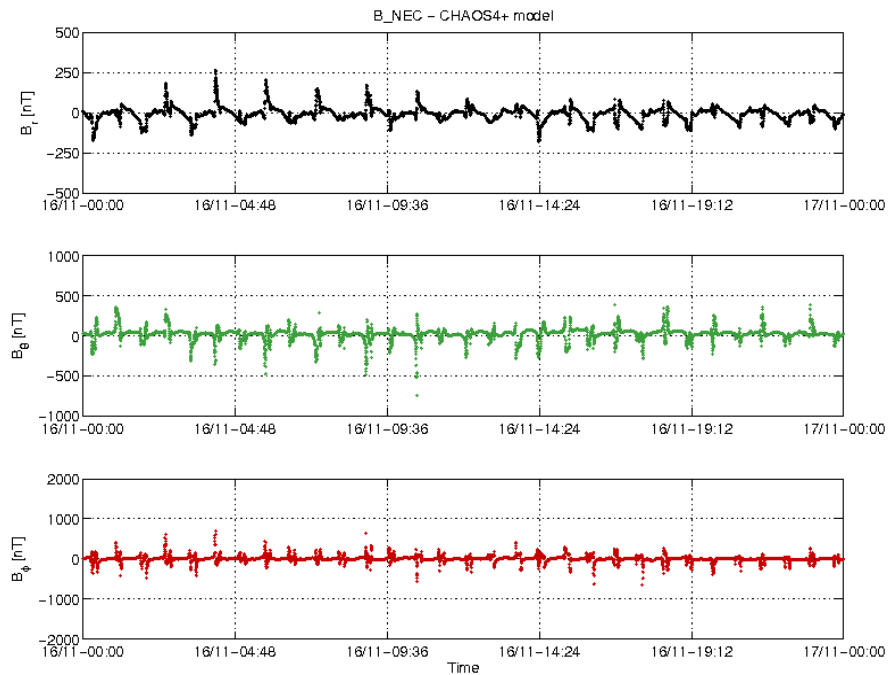**Figure 15:** Swarm A day 16/11 B_NEC - B_Chaos vs colatitude.

Figure 16: Swarm A day 16/11: time series of B_NEC – B_Chaos residuals.
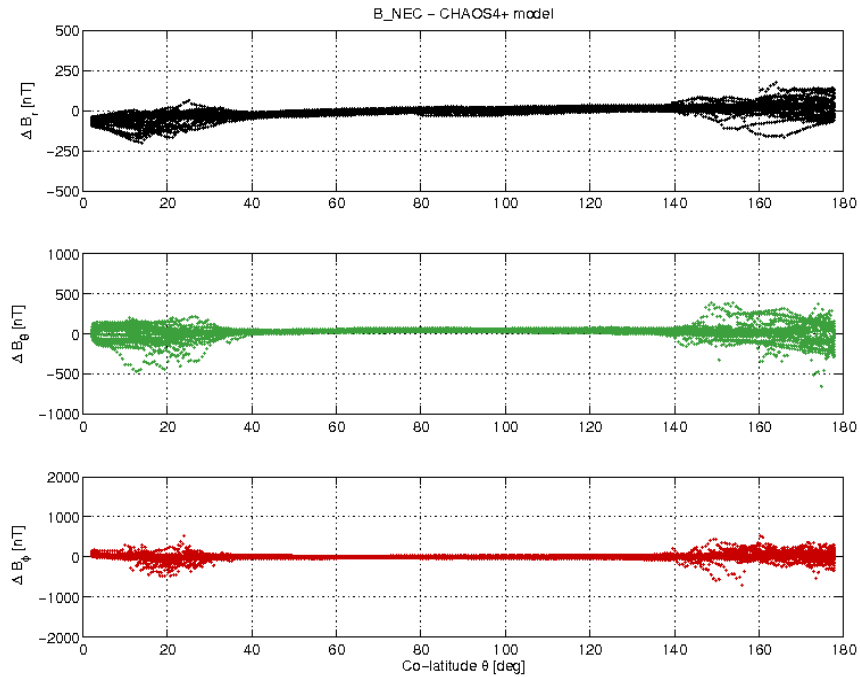
3.3.6.2   Swarm B

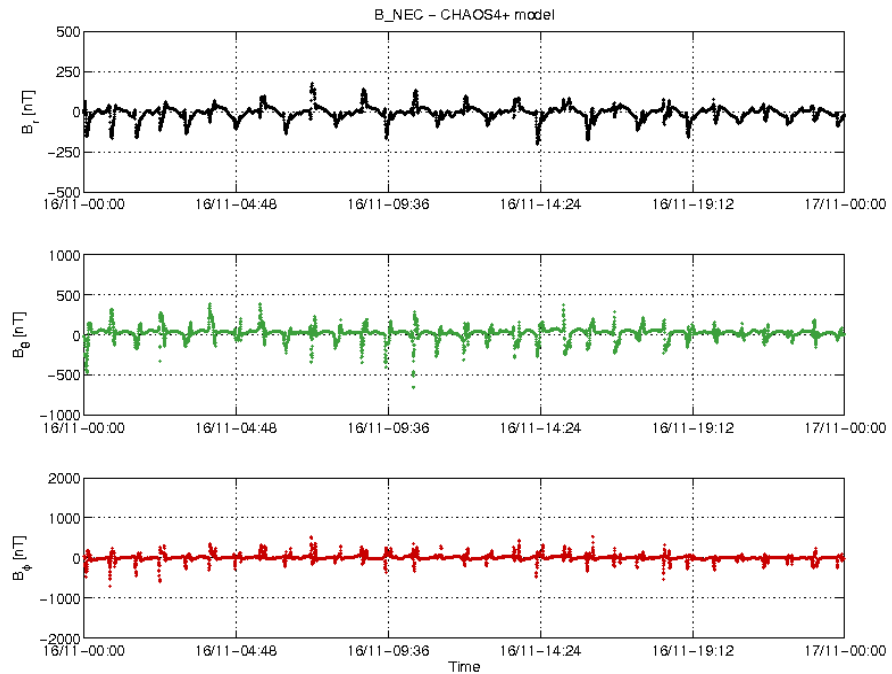**Figure 17** Swarm B day 16/11 B_NEC - B_Chaos difference vs colatitude.

Figure 18 Swarm B day 16/11 time series of B_NEC – B_Chaos residuals.
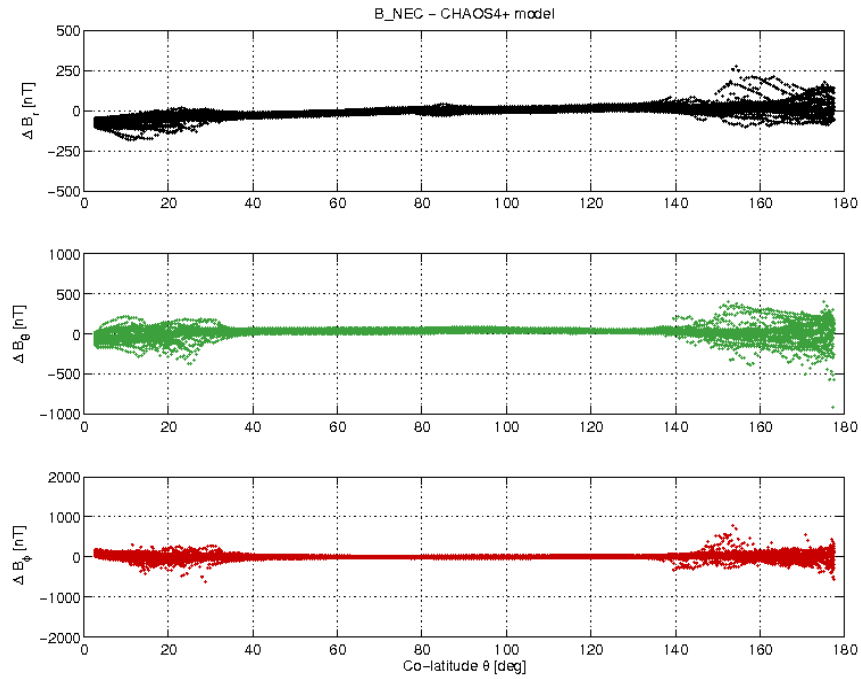
3.3.6.3   Swarm C

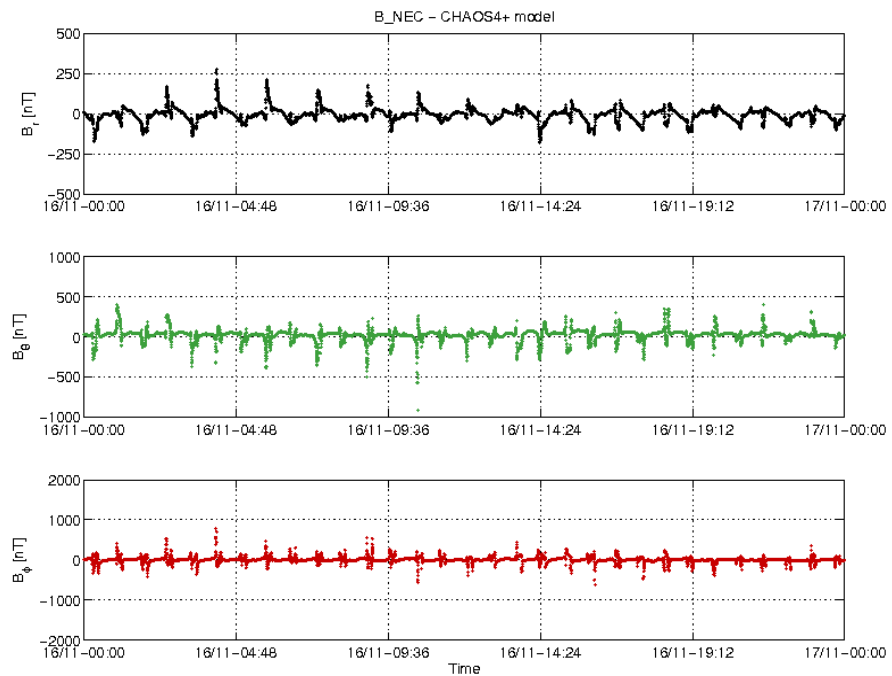**Figure 19** Swarm C day 16/11 B_NEC - B_Chaos difference vs colatitude.

Figure 20 Swarm C day 16/11 time series of B_NEC – B_Chaos residuals.

4.   ON-DEMAND ANALYSIS

4.1   Swarm A ASM-VFM residuals increase during week 45

During week 45 (9-15/11/2015) an anomalous increase of the daily maximum values of the ASM – VFM residuals for Swarm A was reported, as shown in Table 4 below. The maximum is approaching 1 nT, which is the threshold we have identified before to raise a warning towards the ESLs.

Table 4: Week 45 (9-15/11) statistics of the Swarm A ASM-VFM residuals.

Day	Max (nT)	Min (nT)	Standard deviation (nT)	Mean (nT)
09/11	0.86	-0.77	0.32	0.05
10/11	0.85	-0.77	0.32	0.05
11/11	**0.9928**	-0.91	0.36	0.09
12/11	0.9	-0.88	0.34	0.06
13/11	0.84	-0.87	0.33	0.07
14/11	**0.9704**	-0.81	0.32	0.07
15/11	**0.95**	-0.77	0.31	0.05

The relative maximum occurred on 11/11/2015. As shown in Figure 21 and Figure 22, the residuals during that day are well correlated with alpha (azimuth) sun angle, and also with latitude. This strong correlation of residuals and alpha angle means that an update of dB_Sun correction is needed, as confirmed by the ESLs.
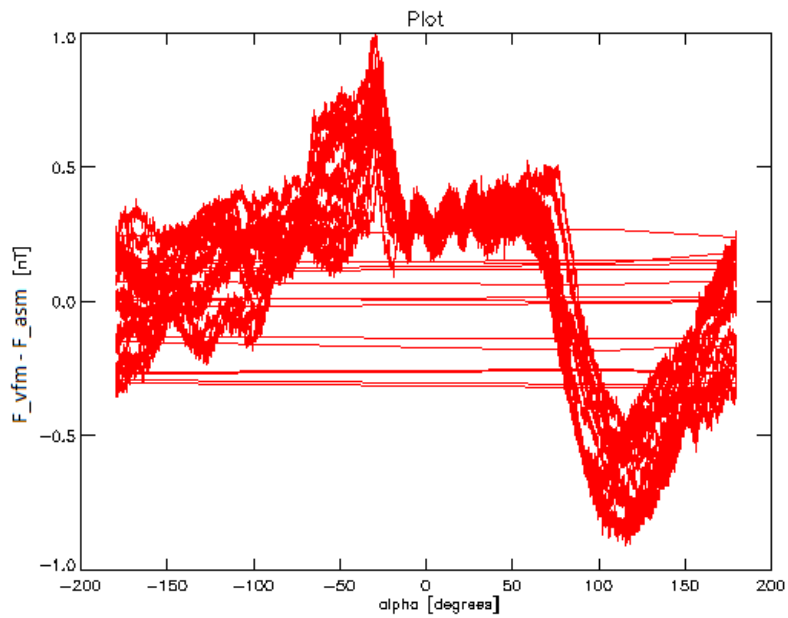
Figure 21 Difference between F_{VFM} and F_{ASM} as a function of alpha - solar inclination angle, rotation about –y axis, S/C frame for the day 11/11/2015. The vertical lines are due to the fact that alpha angle is not continuous in time.
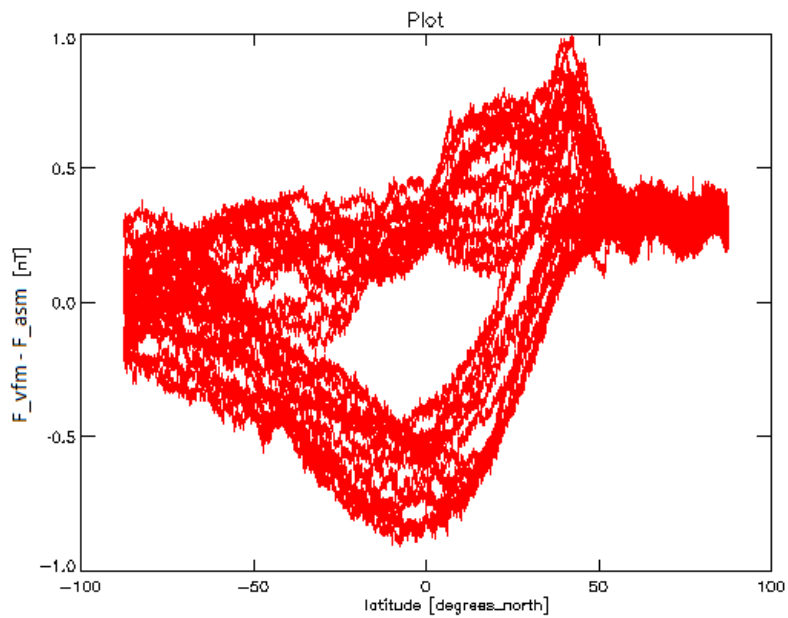

Figure 22 Difference between F_{VFM} and F_{ASM} as a function of latitude for the day 11/11/2015.

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