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IDEAS+ Swarm Weekly Report 2015/37: 2015/09/07 - 2015/09/13

Abstract : This is the **Instrument Data quality Evaluation and Analysis Service Plus** (IDEAS+) Swarm Weekly report on Swarm products quality, covering the period from 09 July to 13 September 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	24 Sep 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 life time, and new parts and complements will be added while the consolidation of knowledge on Swarm data and instruments will progress.

Section 2.1 always gives an overview of the general quality status of the mission instruments and products, while the main observations of the week are summarized in Section 2.2.

The document also includes information on data quality for the three Swarm spacecraft, inferred from automated HTML quality reports which are produced on daily basis for each product. Please contact the 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, user community), anomalies can be triggered and 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, L2-Cat2 1.15
- 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 and TEC 01, FAC 02
- Input auxiliary files baseline: CCDB 0005 (20/07/2015), 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

L1B: the validation of L1B Magnet v3.16 p1 and L1B Plasma v3.16 p2 has been completed. Both the patches have been put in operations the 21st September 2015.

L2-Cat2: A new patch of L2-Cat 2 (v01.15p1) containing the IBI processor has been delivered. In the coming days the PDGS team will perform the first tests.

2.3 Quality Working Group and Cal/Val Coordination

The 5th Swarm Data Quality Workshop was held in Paris (hosted by IPGP) from 07 to 10 September 2015. During the Magnetic splinter session the following decisions have been taken:

➢ **Magnetic Disturbance model**

- The exact source(s) of the disturbance model are still not identified but remains the ultimate goal.
- The co-estimation of VFM parameters and Disturbance model shall result in a physical interpretation
- Thermal filter to be consolidated and introduced in the model
- Lack of physical explanation for Sun dependent scaling, s_{β}.
- For plasma-induced disturbance investigations more information on the platform is needed.

➢ **ASM-Vector data**

- ASM asymmetry to be further investigated
- With a daily alignment, the comparison of B_{ASM} (mapped to VFM) with B_{VFM} yields dBSun(α, β) that is similar to the one determined using scalar characterization.
- A remaining α-dependence in the disturbance model maybe due to the inter-orbital change of rotation.
- Alignment error budget (from industry) could help in developing a thermos-elastic correction approach
- Possibility of building a joint model (α, β dependence) of VFM disturbance (residual) and mechanical distortion.

➢ **STR Interboresight angles**

- Variation correlated to temperature.
- Physical sources under investigation.
- Correction model currently being developed.

➢ **Euler Angle**

- Suggested verification of the aberration correction (not connected to IBA).
- Estimation of VFM-STR alignment (Euler angles) reveals time dependent variations of up to 20”, strongly correlated with LT of orbit: likely caused by un-modeled external field contributions. Effect to be further investigated.
- The Euler angles presently used in L1b processing should be updated → suggestion of having a dedicated working group to define updated Euler angles (static) for next version (re-processing) of L1b data.

2.4 Summary of observations for 2015, Week 37 (09/07 - 13/09)

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

- MAG_CA_1B gaps throughout the week (SW-IDEAS-63), due at times to gaps in the HK telemetry required to compute magnetic stray fields; this is expected from the MAGNET algorithms, nevertheless only a portion of such gaps can be explained by a telemetry rejection, so analyses are still on-going for understanding the reason of the unexplained gaps.

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 37: 09/07 - 13/09.

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	3.1

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, and reported in tables in the sections below, along with some example 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 which is often the most disturbed; in case another component is most affected, it will be specified in parentheses.

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, 09/07 - 13/09, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
09/07	0.11	-6.4	7.7	1.38	
09/08	0.19	-6.6	10.5	1.29	
09/09	0.06	-6.5	6.7	1.27	
09/10	0.10	-5.9	6.5	1.18	
09/11	0.11	-8.6	6.9	1.17	YZZ
09/12	0.16	-7.0	8.4	1.57	XZZ
13/09	0.15	-7.7	8.0	1.32	

Swarm B, 09/07 - 13/09, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
09/07	0.12	-6.5	8.9	1.4	
09/08	0.13	-8.7	9.0	1.3	
09/09	0.10	-7.0	5.8	1.3	
09/10	0.04	-9.3	6.1	1.3	
09/11	0.07	-6.3	7.1	1.3	
09/12	0.15	-7.7	7.3	1.5	
13/09	0.10	-10.0	7.2	1.4	ZYZ

Swarm C, 09/07 - 13/09, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
09/07	0.14	-6.4	8.3	1.3	ZYZ
09/08	0.11	-6.0	5.6	1.2	
09/09	0.03	-7.6	7.9	1.2	
09/10	0.10	-5.2	5.4	1.1	
09/11	0.08	-6.9	6.6	1.1	
09/12	0.20	-7.9	7.6	1.5	
13/09	0.19	-9.6	8.1	1.2	

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 (07/09, Figure 1) in the middle (10/09, Figure 2) and at the end (13/09, 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].

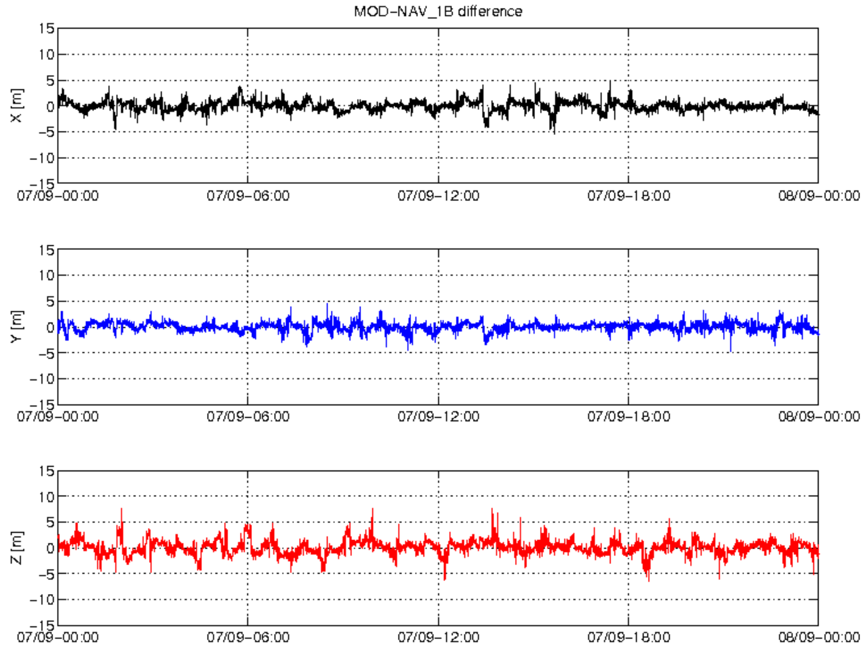

Figure 1: Difference MOD-GPSNAV, S/C A, 07/09. From top to bottom: X, Y and Z axis

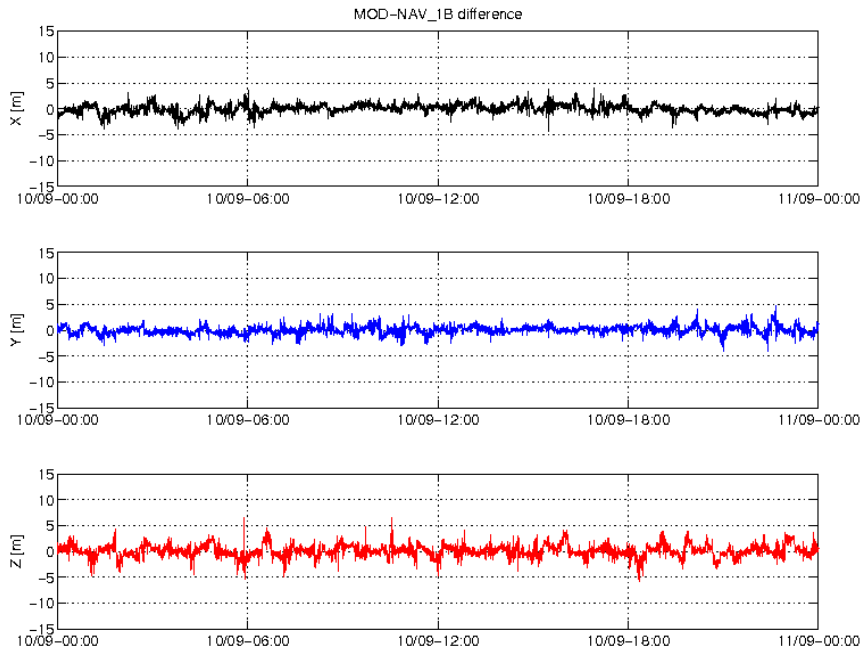

Figure 2: Difference MOD-GPSNAV, S/C A, 10/09. From top to bottom: X, Y and Z axis

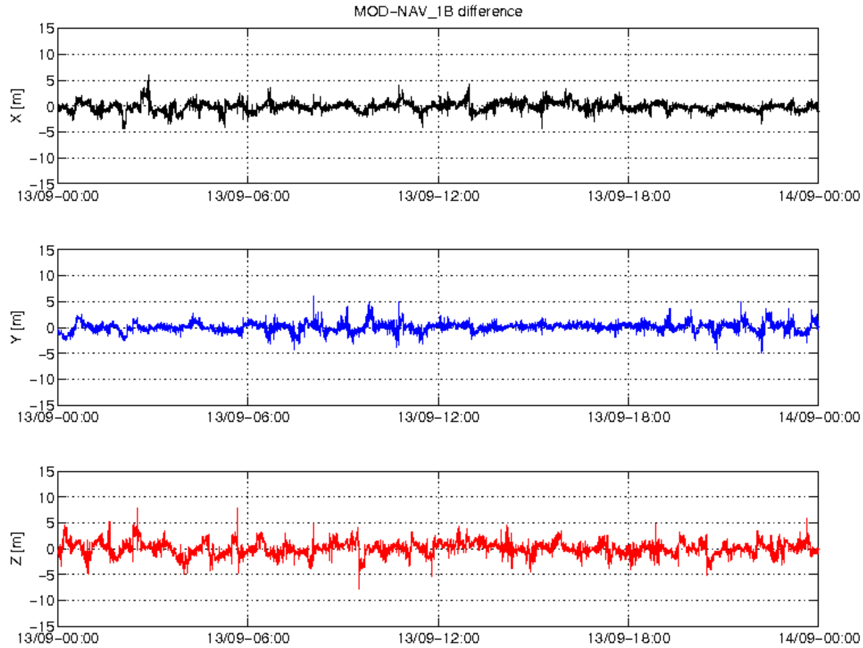

Figure 3: Difference MOD-GPSNAV, S/C A, 13/09. From top to bottom: X, Y and Z axis

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 (07/09, Figure 4), in the middle (10/09, Figure 5), and at end of the week (13/09, Figure 6). 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].

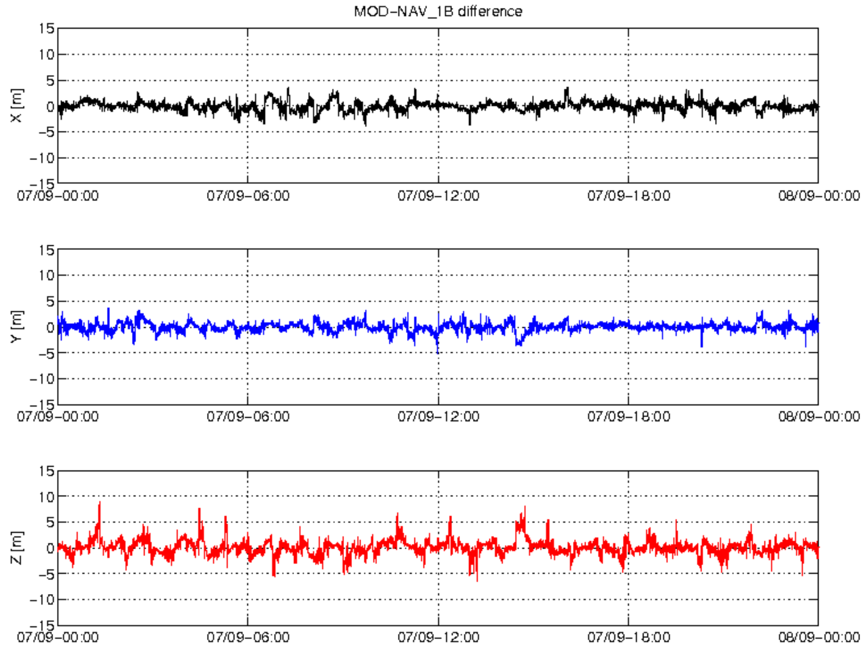

Figure 4: Difference MOD-GPSNAV, S/C B, 07/09. From top to bottom: X, Y and Z axis

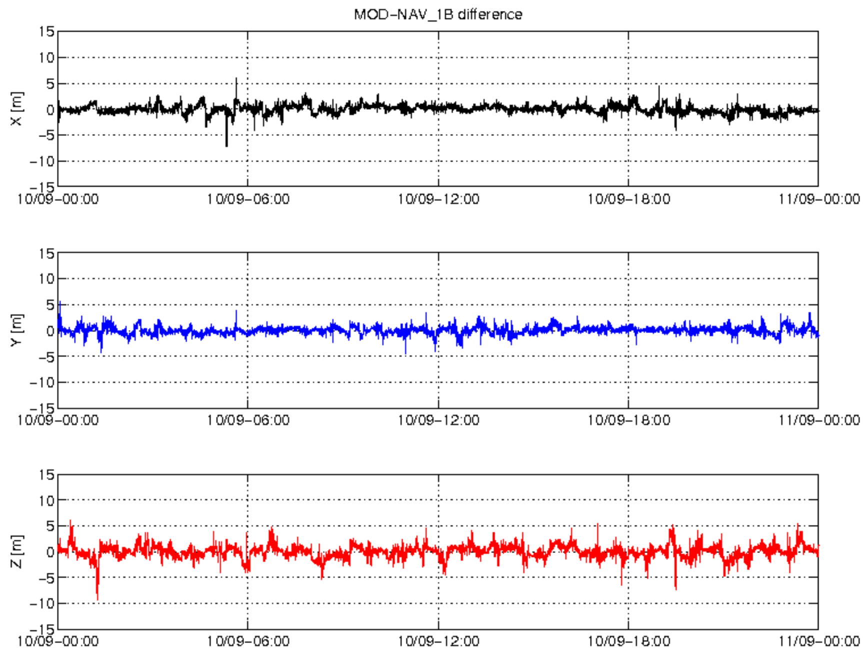

Figure 5: Difference MOD-GPSNAV, S/C B, 10/09. From top to bottom: X, Y and Z axis

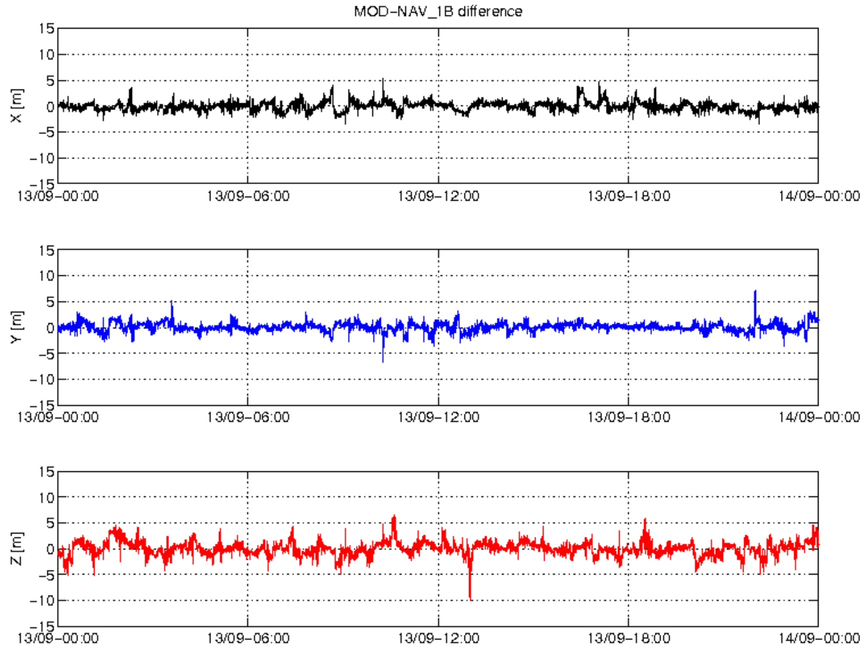

Figure 6: Difference MOD-GPSNAV, S/C B, 13/09. From top to bottom: X, Y and Z axis

3.2.1.3 Swarm C

Below some plot example follows of MOD-NAV differences, S/C C, taken at the beginning of the week (07/09, Figure 7), in the middle (10/09, Figure 8) and at the end (13/09, Figure 9). 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].

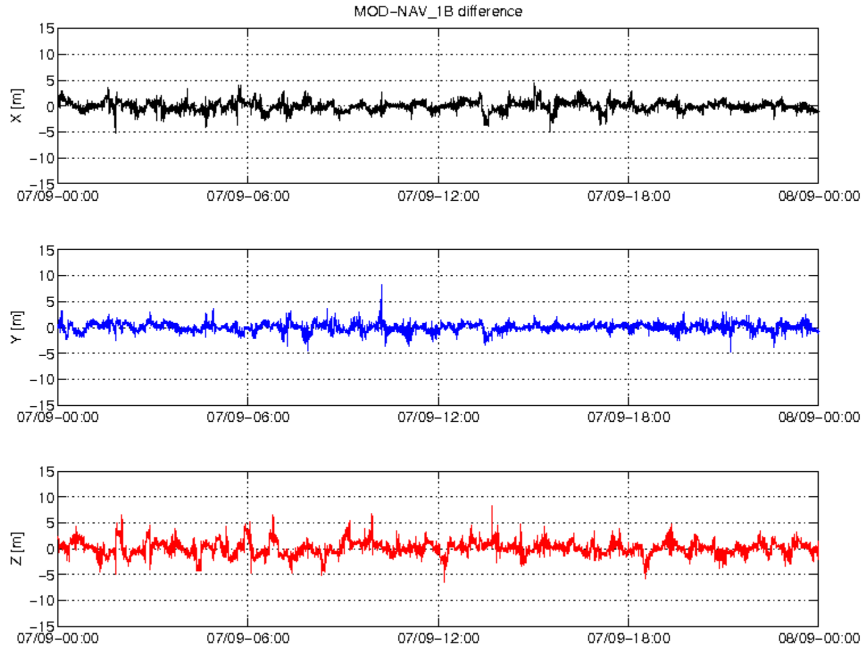

Figure 7: Difference MOD-GPSNAV, S/C C, 07/09. From top to bottom: X, Y and Z axis

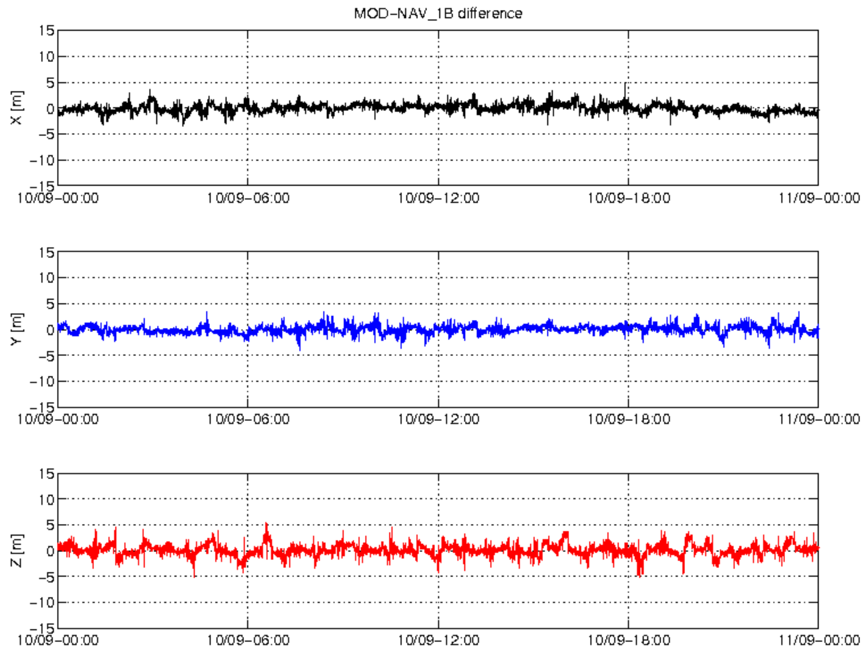

Figure 8: Difference MOD-GPSNAV, S/C C, 10/09. From top to bottom: X, Y and Z axis

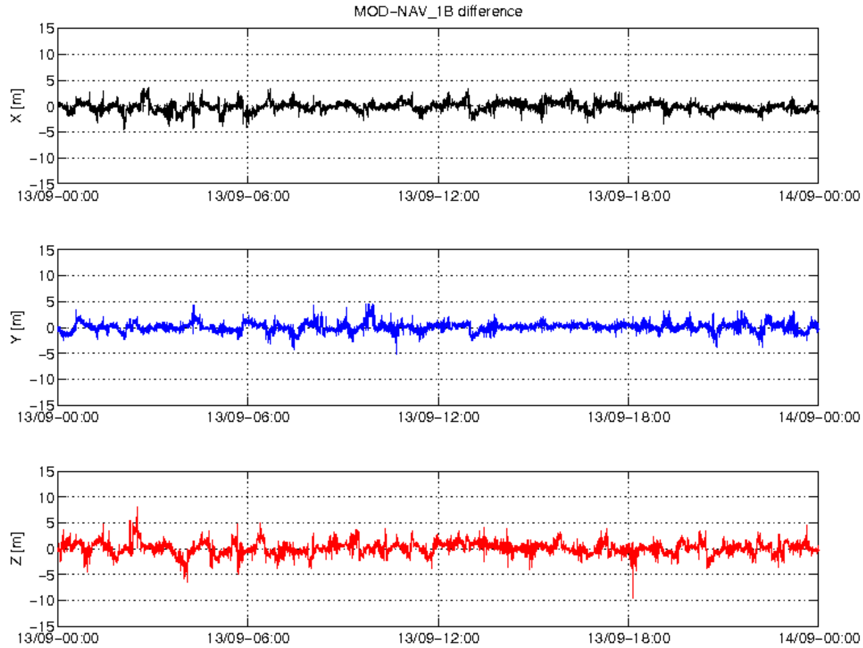

Figure 9: Difference MOD-GPSNAV, S/C C, 13/09. From top to bottom: X, Y and Z axis

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, BNEC and BVFM. 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 |BNEC| - F and recording of daily maximum variations. If +/- 2 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

3.3.1.1 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.

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

Swarm A, 09/07 - 13/09, ASM-VFM difference					
Day	**Max (nT)**	**Min (nT)**	**Standard deviation (nT)**	**Mean (nT)**	**Notes**
09/07	2.2E+00	-2.6E+00	1.6E-01	2.1E-01	
09/08	3.2E+00	-1.9E+00	1.6E-01	2.0E-01	
09/09	3.2E+00	-1.4E+00	1.8E-01	1.8E-01	
09/10	2.2E+00	-6.8E-01	2.3E-01	1.6E-01	
09/11	5.8E+00	-1.3E+00	2.3E-01	1.6E-01	
09/12	8.4E-01	-1.8E+00	2.1E-01	1.3E-01	
13/09	1.4E+00	-1.6E+00	2.1E-01	1.2E-01	
Swarm B, 09/07 - 13/09, ASM-VFM difference					
Day	**Max (nT)**	**Min (nT)**	**Standard deviation (nT)**	**Mean (nT)**	**Notes**
09/07	4.9E+00	-9.2E-01	2.2E-01	3.3E-01	
09/08	2.8E+00	-2.5E+00	2.2E-01	3.1E-01	
09/09	2.7E+00	-1.9E+00	2.2E-01	2.9E-01	
09/10	2.0E+00	-6.4E-01	2.2E-01	2.7E-01	
09/11	3.5E+00	-2.0E+00	2.1E-01	2.6E-01	
09/12	8.1E-01	-3.2E-01	2.0E-01	2.4E-01	
13/09	1.3E+00	-4.4E-01	1.9E-01	2.3E-01	

In Figure 10 and Figure 11 one can see the plots of the daily mean and the standard deviation since 17/08/2015 for both S/C A and S/C B.

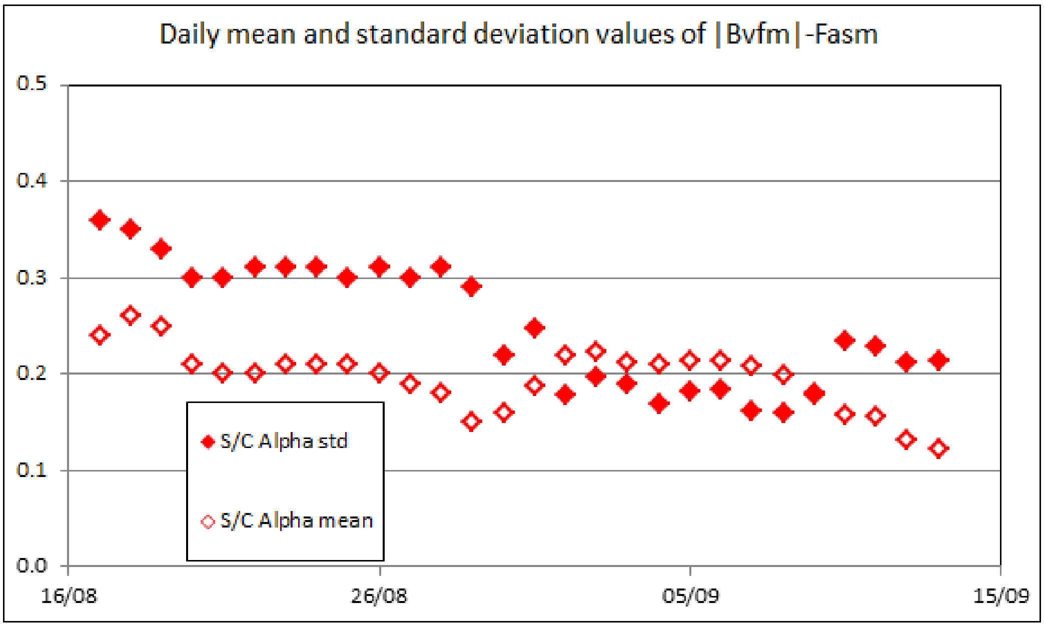

Figure 10: Daily mean and standard deviation values of ASM-VFM residuals (defined as dF=|B_{VFM}|-F_{ASM}) for S/C Alpha.

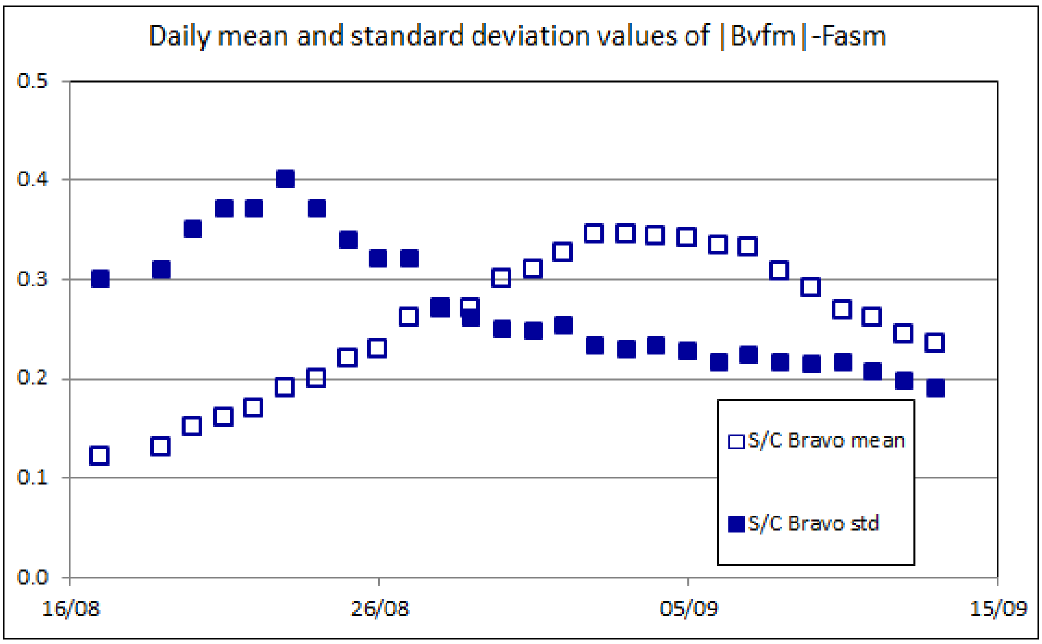

Figure 11: Daily mean and standard deviation values of ASM-VFM residuals (defined as dF=|B_{VFM}|-F_{ASM}) for S/C Bravo.

3.3.1.2 Swarm A

The daily peak-to-peak difference around the week stays within [-0.3, 0.7] nT with a few spikes not exceeding 2nT and two spikes of about 6nT on 11/09. Below two example plots of such differences for the days: 07/09 (Figure 12), and 13/09 (Figure 13).

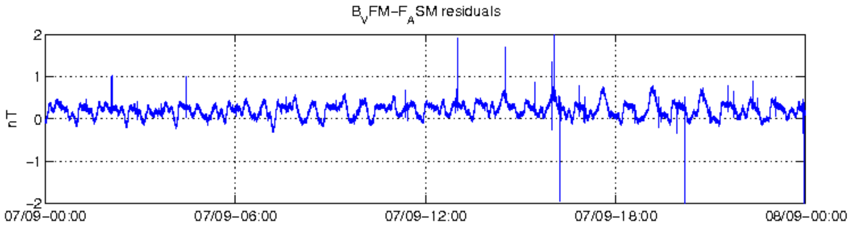

Figure 12: ASM-VFM residuals for S/C A, 07/09.

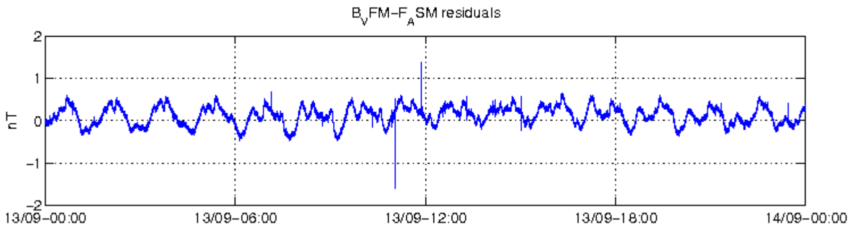

Figure 13: ASM-VFM residuals for S/C A, 13/09.

3.3.1.3 Swarm B

The daily peak-to-peak difference around the week is, on average: [-0.3, 0.8] nT, with a few spikes not exceeding 2 nT and one spike of 5nT on 09/07. Below two example plots follows of such differences: 07/09 (Figure 14), and 13/09 (Figure 15).

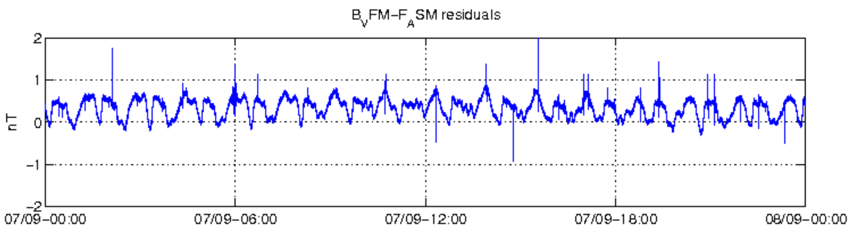

Figure 14: ASM-VFM residuals for S/C B, 07/09.

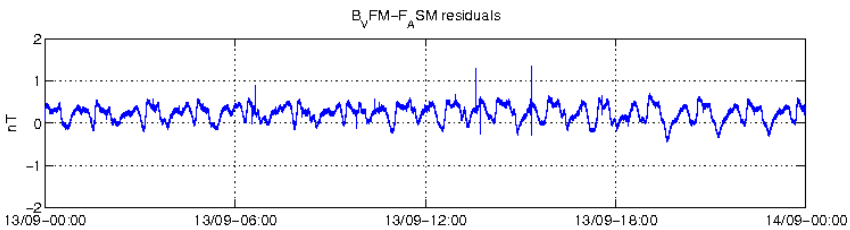

Figure 15: ASM-VFM residuals for S/C B, 13/09.

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 Alpha and Bravo 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 Alpha and Bravo for reported period the temperatures behaved as expected.

3.3.4 Magnetic time series visual inspection

3.3.4.1 Swarm A

An example of representative magnetic field time series for S/C A (13/09) can be seen in Figure 16 below.

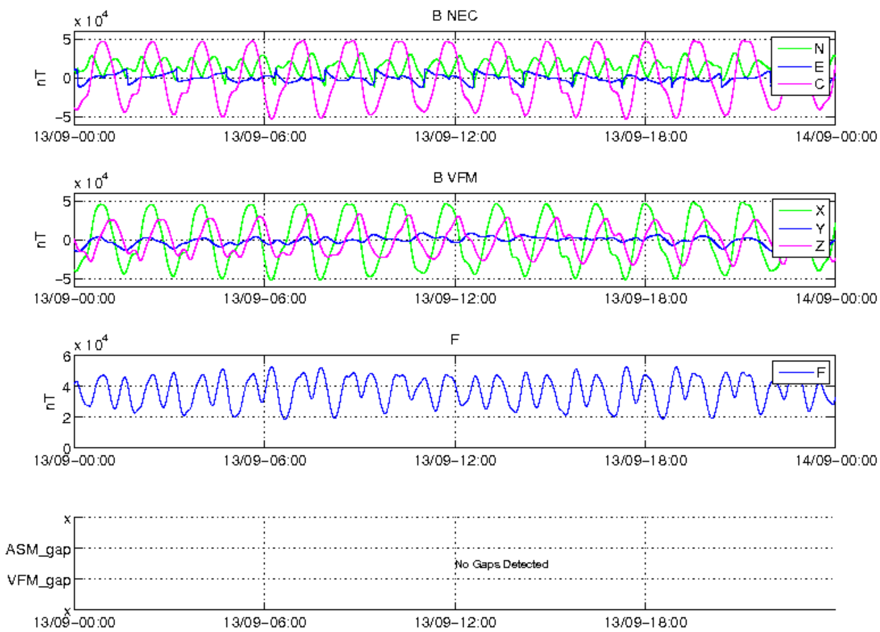

Figure 16: Time series of the geomagnetic field, for 13/09, S/C A. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM, and location of gaps (if any).

3.3.4.2 Swarm B

An example of representative magnetic field time series for S/C B (13/09) can be seen in Figure 17 below.

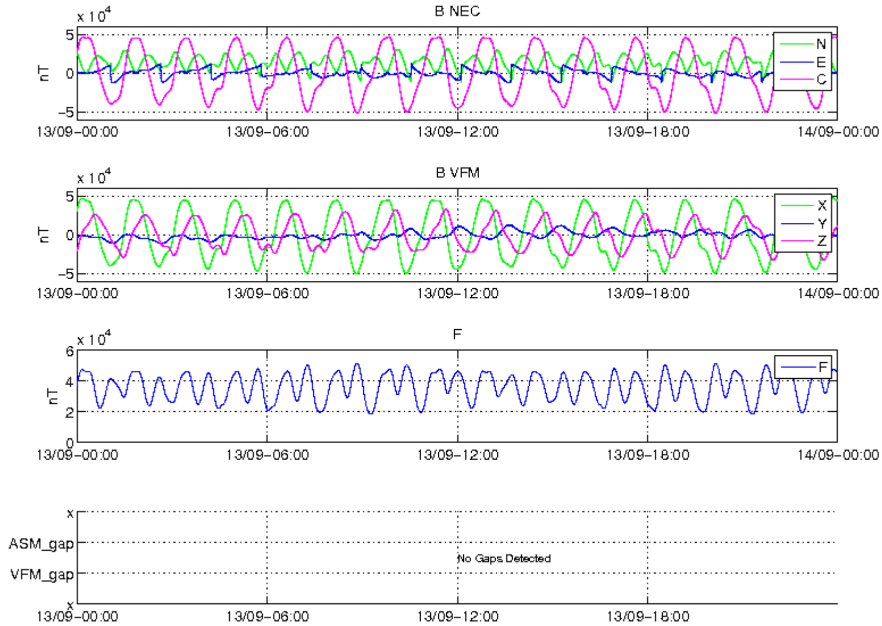

Figure 17: Time series of the geomagnetic field for 13/09, S/C B. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM, and location of gaps (if any).

3.3.4.3 Swarm C

An example of magnetic field time series for S/C C (13/09) can be seen in Figure 18.

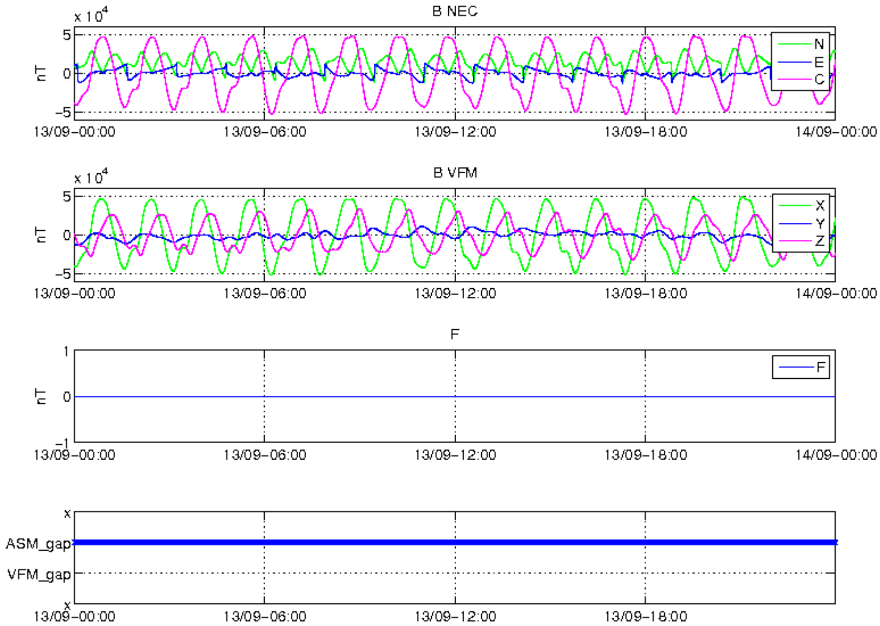

Figure 18: Time series of the geomagnetic field for 13/09, S/C C. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM (no data here because ASM it is off) and location of gaps.

3.3.5 B_{NEC} vs Chaos4plus model residuals

Figure 19, Figure 21 and Figure 23 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 20, Figure 22 and Figure 24 shows, from top to bottom, the time series on 09/07 of: (1-2-3) residuals of B_{NEC}-B_{CHAOS} by components, related to Swarm Alpha, Bravo and Charlie respectively,

The component most affected by residual spikes and variations is Bθ_NEC, i.e. the component which 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

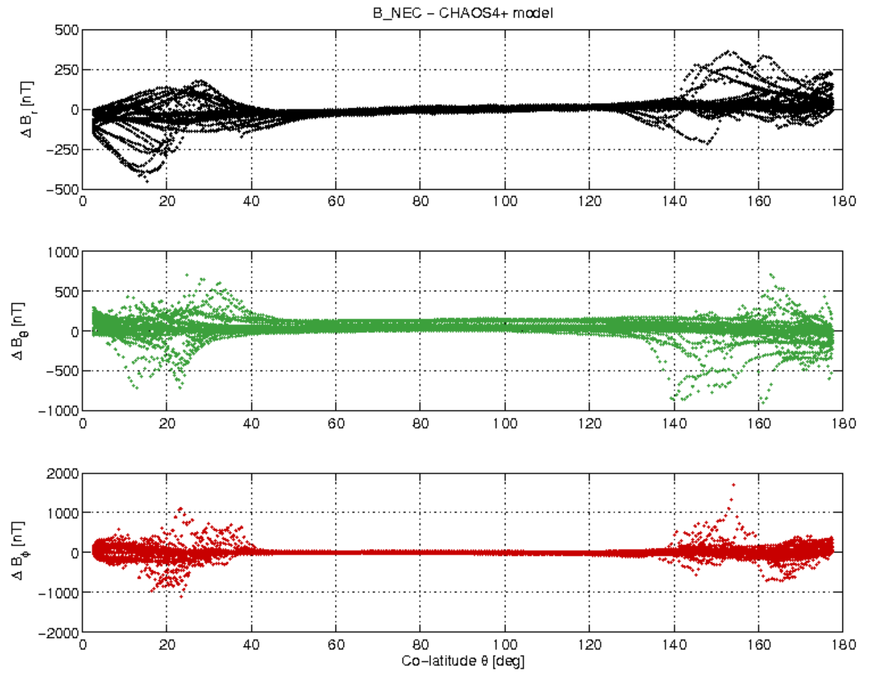

Figure 19: Swarm A day 07/09 B_NEC - B_Chaos difference vs colatitude.

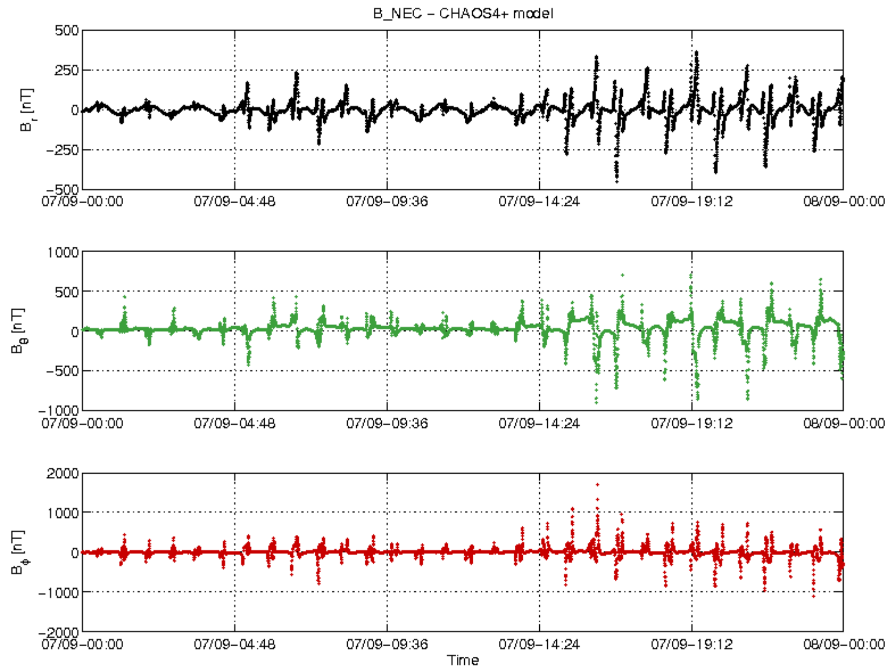

Figure 20: Swarm A day 07/09: time series of B_NEC – B_Chaos residuals.

3.3.5.2 Swarm B

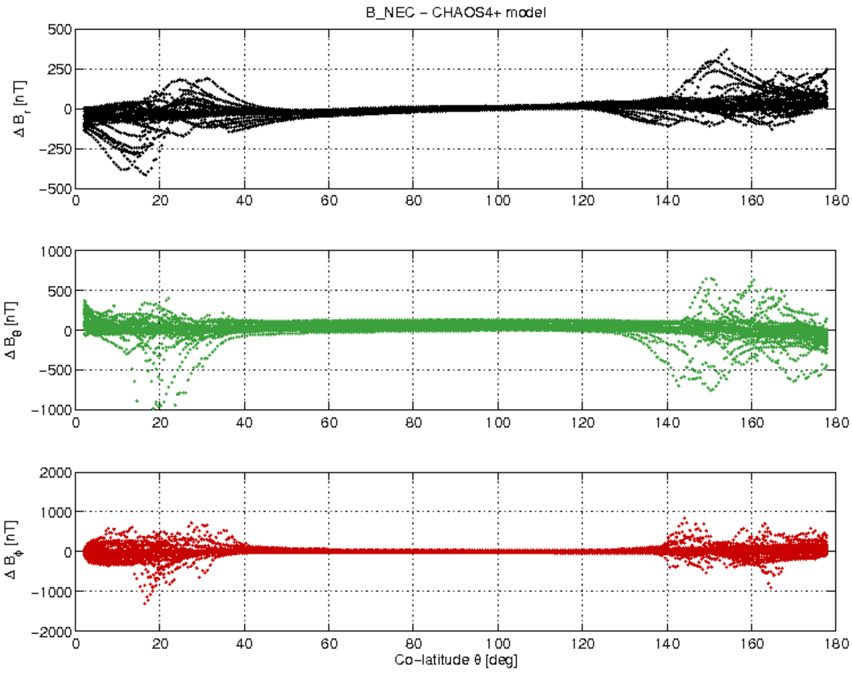

Figure 21: Swarm B day 07/09 B_NEC - B_Chaos difference vs colatitude.

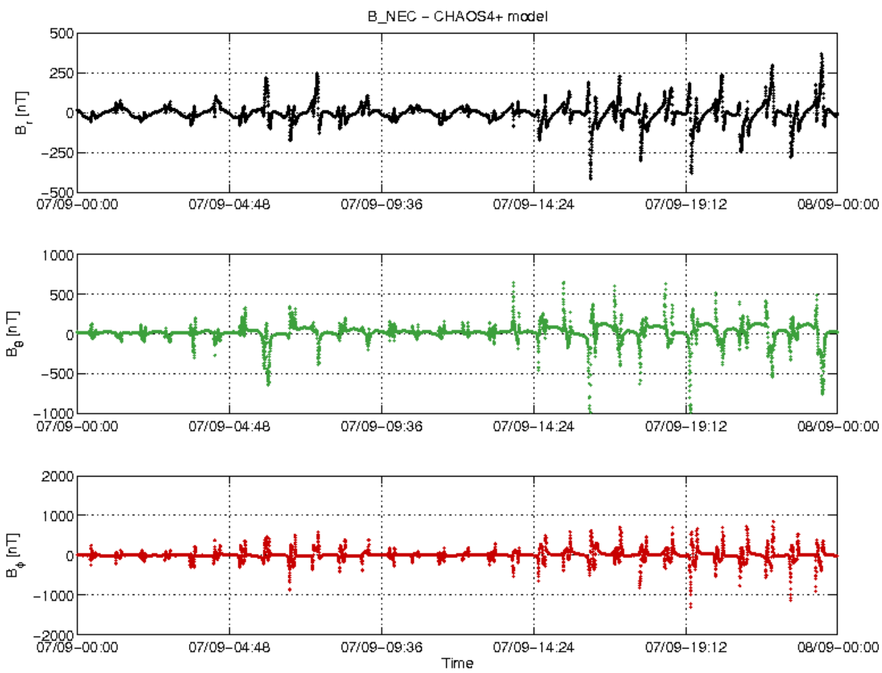

Figure 22: Swarm B day 07/09 time series of B_NEC – B_Chaos residuals.

3.3.5.3 Swarm C

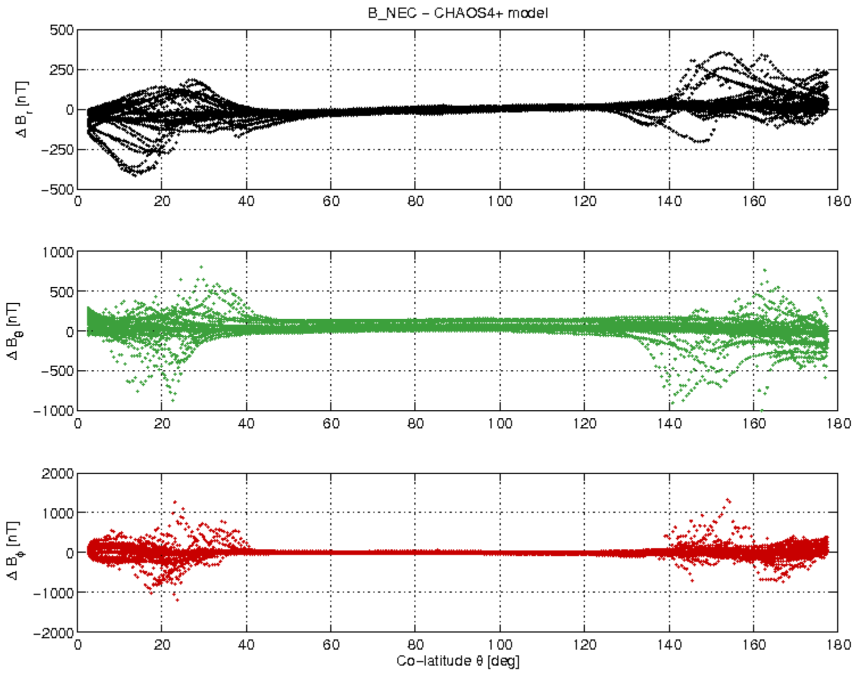

Figure 23: Swarm C day 07/09 B_NEC - B_Chaos difference vs colatitude.

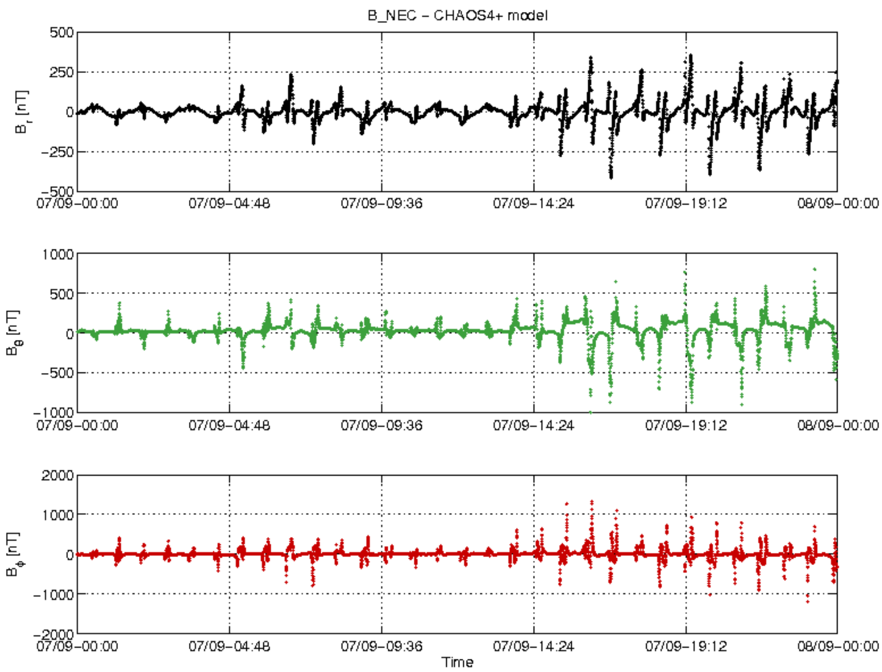

Figure 24: Swarm C day 07/09 time series of B_NEC – B_Chaos residuals.

4. ON-DEMAND ANALYSIS

Nothing to report.

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