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IDEAS+ Swarm Weekly Report 2015/27: 2015/06/29 - 2015/07/05

Abstract : This is the **Instrument Data quality Evaluation and Analysis Service Plus** (IDEAS+) Swarm Weekly report on Swarm products quality, covering the period from 29 June to 05 July 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	15 Jul 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 3.15, L2-Cat2 1.12
- L0 input products baseline: 02
- L1B baseline: 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: 01
- Input auxiliary files baseline: CCDB 0003, ADF 0101
- MPPF-CVQ v.2.14.00

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

EFI-TII: During the last two weeks of July an operational scenario of 2 active orbits per day will be tried for Swarm A and B, both consecutive and non-consecutive. Swarm C will undergo through a further cycle of fixed MCP voltage tests: TII will be commanded into ACTIVE state during 1 orbit per day with fixed MCP voltage on both sensors (Automatic Gain Control is DISABLED). Each day the Phosphor Voltage will be +3 kV or +5 kV, alternating the voltage each day (i.e. 1st day: +3 kV, 2nd day: +5 kV, 3rd day: +3 kV, etc.).

In summary, the results of the past weeks analysis when the TII operated 1 orbit per day for all S/C are still under evaluation. There are first evidences of extended periods of images good quality, but with remarkable differences between parts of the orbits on the day and on the night sides, and magnetic latitude. Often sharp transitions from highly variable and strong second y moments to low and steady values are observed close to geomagnetic equator.

2.2 Plan for operational processor updates

Discrepancies have been found is two scenarios of the integration tests for L1BOP 3.16. The manufacturer has already investigated and spotted the anomaly: a variable for a diagnostic parameter (ASM_freq_dev) is not correctly initialized in case of partial ASM input coverage. The issue is not blocking for the deployment in operations, but GMV will nonetheless prepare a patch that will be delivered, tested and deployed before to start the reprocessing.

DTU has delivered new CCDB updates, which are unexpectedly numerous and time expensive to check and test. This has delayed by some days the deployment of the processor into operations: two new test scenarios have been prepared and shared with DTU for further verification of the goodness of the new CCDBs. First feedbacks are encouraging, and, provided no surprises pop up in the coming days, the L1BOP 3.16 could be deployed during week 30 (20-24/07).

Nevertheless, the PDGS will wait some more time before to start the reprocessing campaign. This is due to the following reasons:

1. An assessment of basic data quality is envisaged with the new operational products, involving off-line checks of the IDEAS+ team and interactions with the mission experts.
2. The processor patch mentioned above shall be deployed.
3. New versions of the quality control tools have to be integrated in the system (DQC and CVQ).

2.3 Quality Working Group and Cal/Val Coordination

Coordination is is in place for organizing the 6th Swarm Data Quality Workshop in Paris (hosted by IPGP) from 7 to 10 September 2015.

Following the QWG recommendations in Potsdam and the scientists need in view of the IUGG conference in June, the preliminary plasma dataset has been released early February 2015.

DTU/ESL shared the final set of corrected data on early April. These corrected data also contain the dB_sun correction, providing the users the possibility to access to uncorrected data.

The Task Force meeting was held on 9-10 April in ESTEC. During this meeting the following decisions have been taken:

- ESA and CNES have to be prepared for potential further ASM failures scenarios.
- The corrected data provided by Lesur-Tøffner-Clausen (DTU) will be distributed by ESA to all Swarm users[1]. Soon, the correction will also be implemented in the OP. Meanwhile, the team agreed that the following investigation should be done:
  i. Clarifications of coordinate systems used (and left out) in models. To confirm overall dynamics and time constants / phase shifts.
  ii. Splinter group with Airbus, DTU-MI, and ESA to further coordinate investigations of "secondary" contributions.
  iii. (v x B) further investigations during: 1) the 4-step-360 rotation data, 2) the Alpha-Charlie rotations.
  iv. Test with same sun attitude conditions (excluding manoeuvres) but different plasma conditions or magnetic longitude.
  v. To better quantify (from models) potential plasma-related effects. Link to MAGx_HR.
  vi. Involvement of EFI-TII team.

Another task force meeting has been held in Friedrichshafen the **2-3 July 2015**. Soon more details will be given on the main conclusions.

[1] *The corrected Swarm magnetic data have been distributed to all Swarm users on 13/04 (https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/swarm/news/-/article/corrected-swarm-magnetic-data-now-available).*

2.4 Summary of observations for 2015, Week 27 (29/06 - 05/07)

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

- **Several few seconds gaps in MAGx_CA_1B products** throughout the week. Most of them associated to gaps in telemetry (L0 products are continuous, due to processing some are discarded and a gap in L1A occurs). Monitoring on-going.
- **Missing production for days 30/06 and 01/07.** This seems to be related to the introduction of a leap second at midnight between 30/06 and 01/07: a timestamp duplication occurs in the STR telemetry not in line with what is expected.

3. ROUTINE QUALITY CONTROL

3.1 Gaps analysis

1. **Missing production** for Swarm A and B for days 30/6 and 01/07. Missing Magnet and Plasma production for Swarm C for days 30/6 and 01/07. ORBATT processors fail with the message: "*Swarm exception caught: No STR attitude data available.*", the MAGNET on Swarm C fails with the message: "*Swarm exception caught: linearInterpolation() not performed: Input time and data are not sorted by time.*"

   The suspicion is that such failures (at least the ORBATT ones) could be related to the leap second introduction, occurred at midnight between 30/06 and 01/07. In particular, for the STR Level 0 data, there is a timestamp duplication at 00:00:01 of 01 July (example for CHU1 on S/C A):

   01JUL2015 00:00:01.982000

   01JUL2015 00:00:01.990000

   This stands for both Swarm A and B, while for Swarm C the second 00:00:00 is duplicated. It seems like the processor is not able to handle STR duplicated data in some situation. The issue is under investigation by the manufacturer.

2. **MAGx_CA gaps**
   a. S/C A
      i. 29/06, 02/07, 03/07, 04/07, 05/07 all due to gap in bus telemetry or AOCS (MAGA_HR flags platform =5 or 129),
   b. S/C B
      i. 29/06, 03/07, 04/07 due to gap in bus telemetry or AOCS (MAGA_HR flags platform =5 or 129),
      ii. 05/07 Flags_f=49 (Gap in 4 nearest ASM samp.)

Whether bus gaps were always present in the original telemetry, or some data has been discarded in the conversion from Level 0 into Level 1A, is still something under investigation.

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 27: 29/06 - 07/05.

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, 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, 29/06 - 07/05, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
29/06	0.16	-6.1	6.8	1.29	
30/06	N/A	N/A	N/A	N/A	No data
07/01	N/A	N/A	N/A	N/A	No data
07/02	0.09	-6.7	5.7	1.22	
07/03	0.19	-5.3 (Y)	8.1	1.36	
07/04	0.09	-7.4	6.4	1.25	
07/05	0.1	-8.1	7.1	1.24	
Swarm B, 29/06 - 07/05, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
29/06	0.06	-7.4 (Y)	8.1	1.36	
30/06	N/A	N/A	N/A	N/A	No data
07/01	N/A	N/A	N/A	N/A	No data
07/02	0.08	-5.8	6.4 (X)	1.22	
07/03	0.09	-6.5	9.7 (X)	1.29	
07/04	0.14	-5.1	6.8	1.22	
07/05	0.12	-5.7(Y)	7.3	1.29	
Swarm C, 29/06 - 07/05, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
29/06	0.11	-5.6	6.4	1.26	
30/06	0.15	-7.4	7.7	1.33	
07/01	**3.27**	**-6906**	**3087**	**141.5**	One single big spike at the beginning of the day
07/02	0.07	-8.6	8.1	1.18	
07/03	0.18	-5.7	8.2	1.36	
07/04	0.12	-6.1	6.2	1.23	
07/05	0.07	-6.8	6	1.18	

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 (29/06, Figure 1) in the middle (02/07, Figure 2) and at the end (05/07, 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].

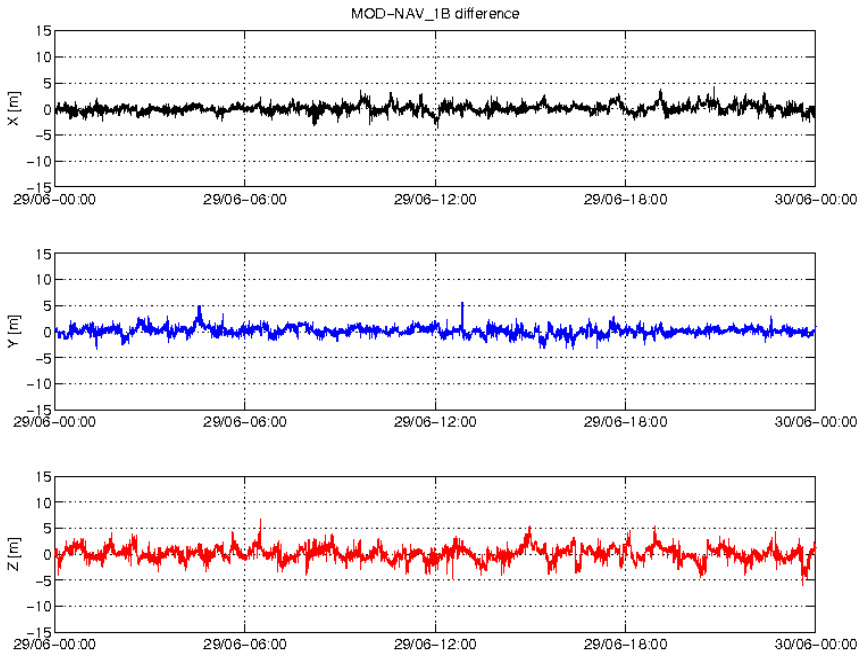

Figure 1: Difference MOD-GPSNAV, S/C A, 29/06. From top to bottom: X, Y and Z axis

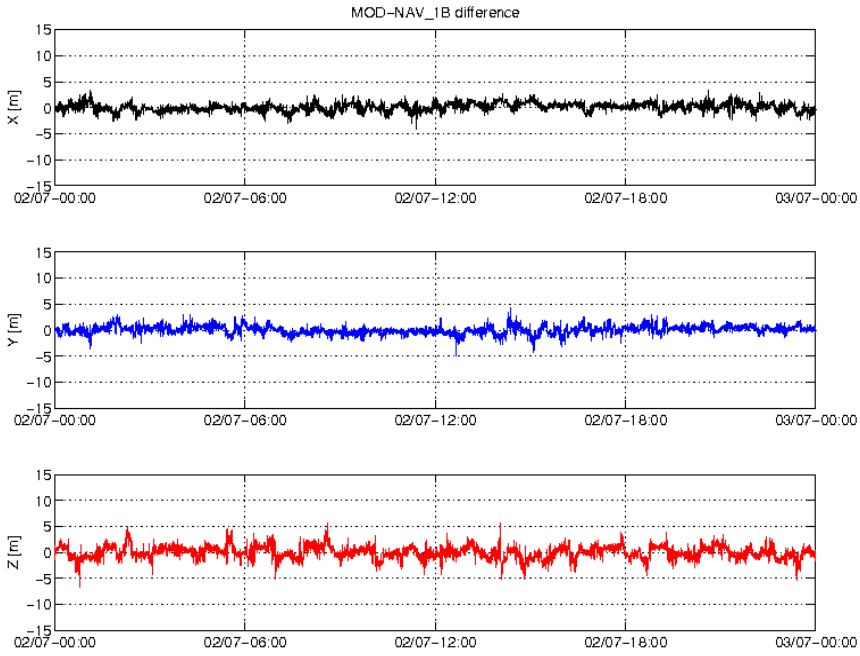

Figure 2: Difference MOD-GPSNAV, S/C A, 02/07. From top to bottom: X, Y and Z axis

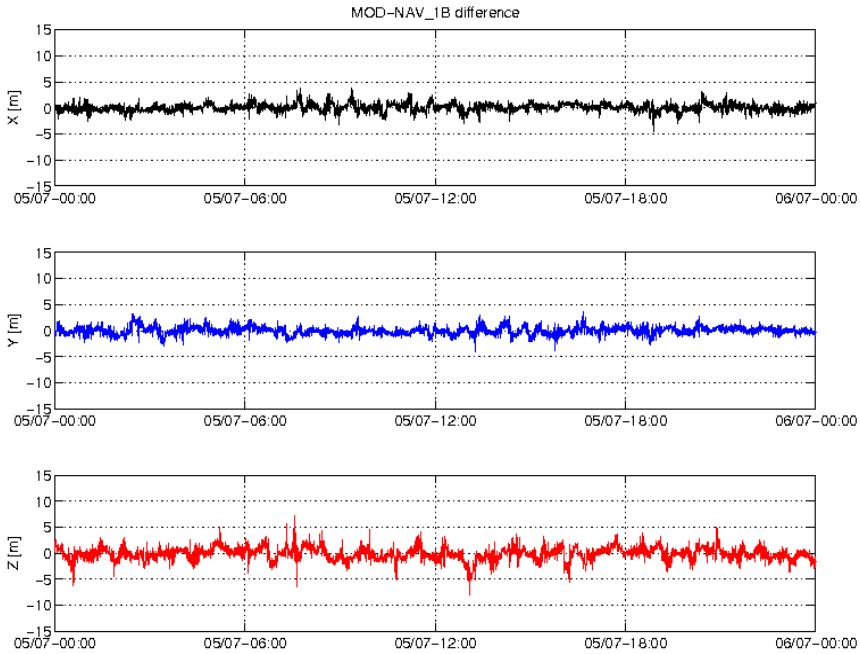

Figure 3: Difference MOD-GPSNAV, S/C A, 05/07. From top to bottom: X, Y and Z axis

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 (29/06, Figure 4), in the middle (02/07, Figure 5), and at end of the week (05/07, 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].

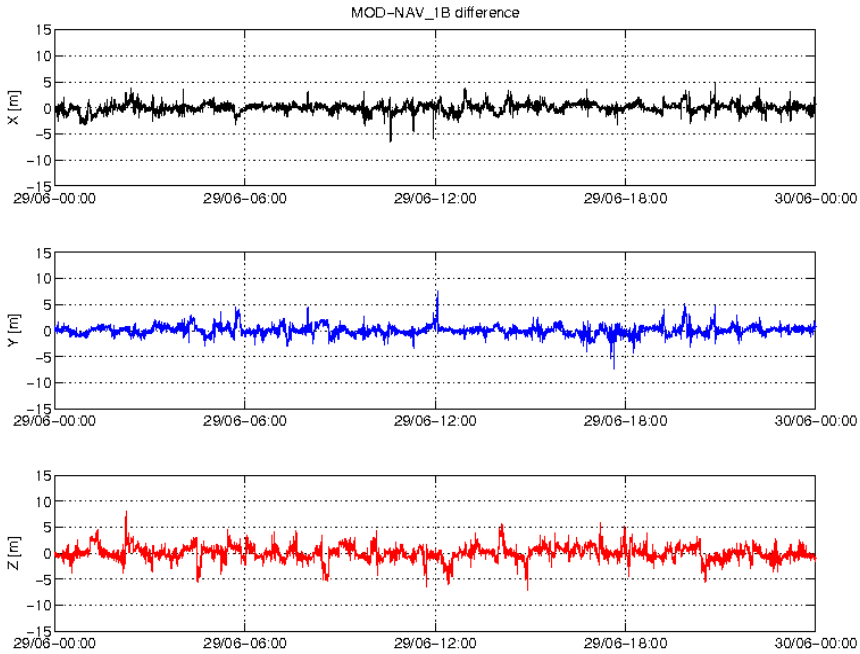

Figure 4: Difference MOD-GPSNAV, S/C B, 29/06. From top to bottom: X, Y and Z axis

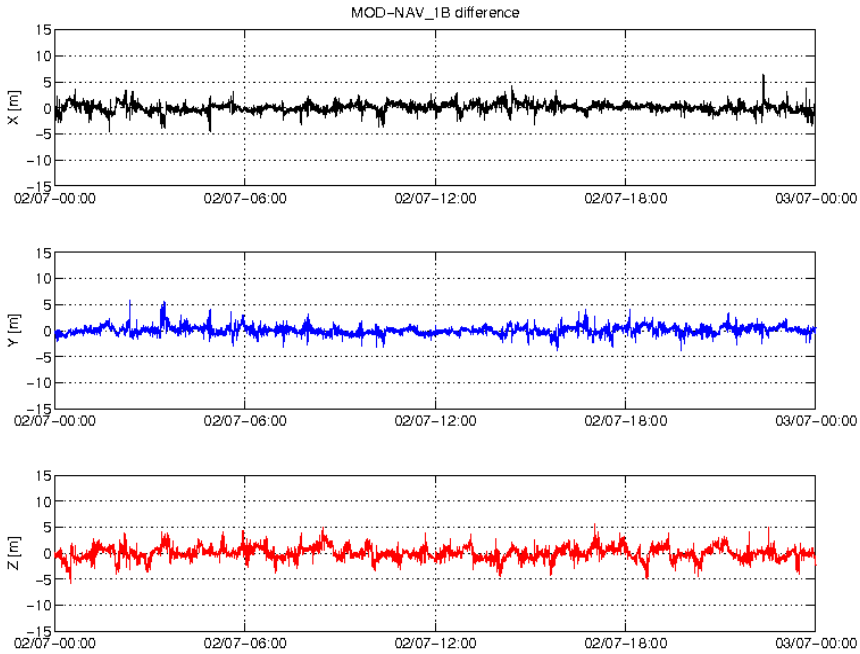

Figure 5: Difference MOD-GPSNAV, S/C B, 02/07. From top to bottom: X, Y and Z axis

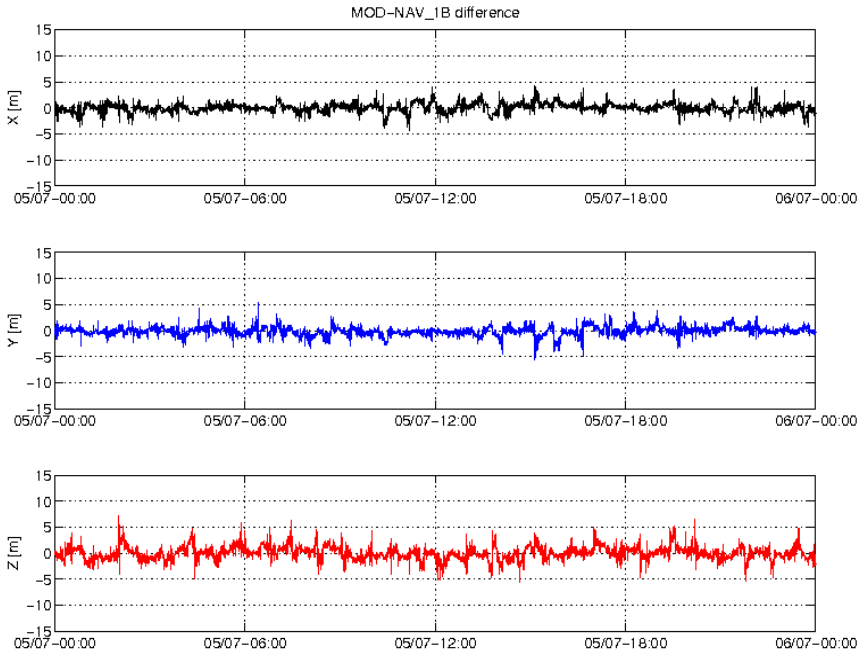

Figure 6: Difference MOD-GPSNAV, S/C B, 05/07. From top to bottom: X, Y and Z axis

3.2.1.3 Swarm C

Below some plot example of MOD-NAV differences, S/C C, follows, taken at the beginning of the week (29/06, Figure 7), in the middle (02/07, Figure 8) and at the end (05/07, 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].

At 00:00:00 on July 01 a huge spike is observed in all components of the MOD-NAV difference. The spike has actually the value of the position itself, as if the MOD solution was not calculated at all. We think this is another effect of the Leap second introduction.

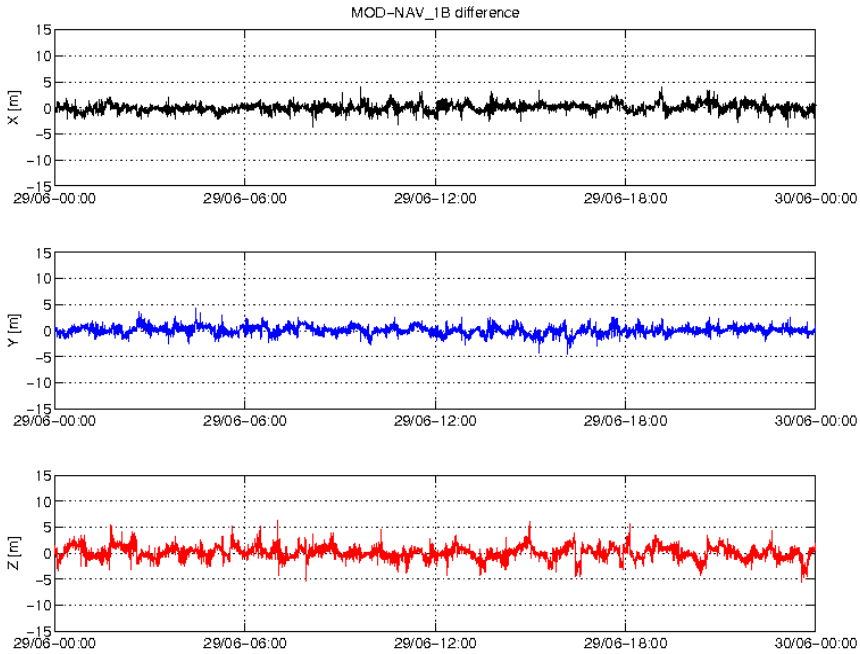

Figure 7: Difference MOD-GPSNAV, S/C C, 29/06. From top to bottom: X, Y and Z axis

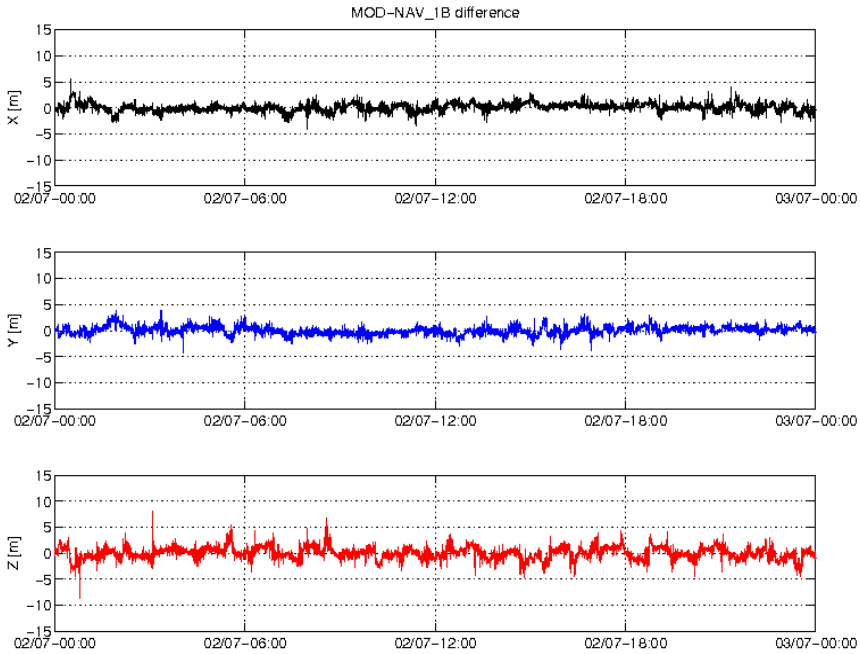

Figure 8: Difference MOD-GPSNAV, S/C C, 02/07. From top to bottom: X, Y and Z axis

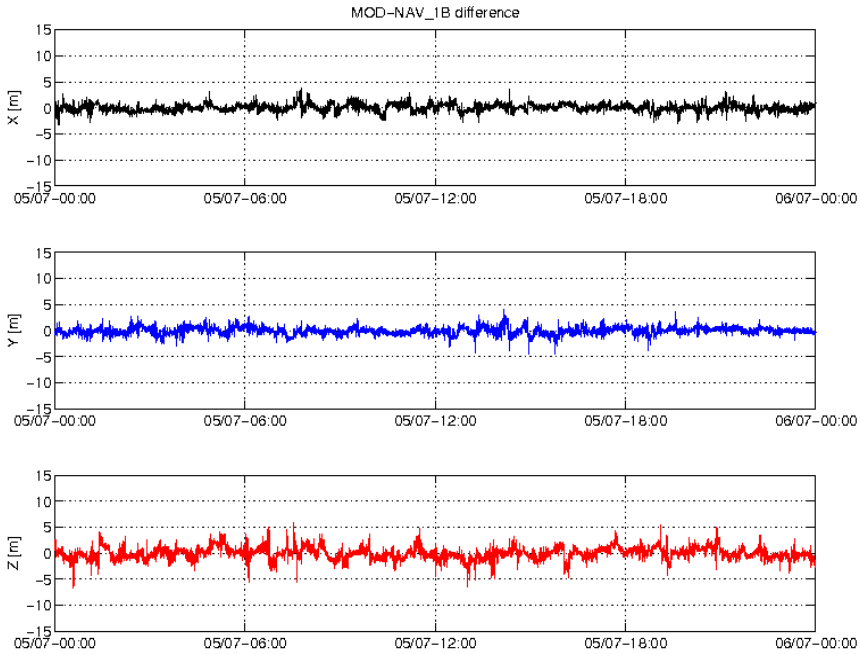

Figure 9: Difference MOD-GPSNAV, S/C C, 05/07. From top to bottom: X, Y and Z axis

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:

- TCF.VFM parameters monitoring (VFM calibration parameters): series of biases, scales, non-orthogonality factors and RMS. **This check is performed on monthly basis.**
- ASM instrument monitoring: quartz frequency and ASM temperature
- VFM instrument monitoring: temperatures
- Visual inspection of daily time series of magnetic field intensity F, $\mathbf{B}_{\mathbf{NEC}}$ and $\mathbf{B}_{\mathbf{VFM}}$. 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 **VFM-ASM known anomaly**: visual inspection of $|B_{NEC}|$ - F and recording of daily maximum variations. If +/- 5 nT are exceed on a given day, an alert is raised.
- Comparison of magnetic data (BNEC) with a model (Chaos4plus);

3.3.1 ASM-VFM difference statistics

In Table 3, one can see the statistics of the differences between 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, 29/06 - 07/05, ASM-VFM difference				
Day	**Max (nT)**	**Min (nT)**	**Standard deviation (m)**	**Notes**
29/06	1.6E+00	-2.0E+00	9.1E-01	
30/06	N/A	N/A	N/A	No data
07/01	N/A	N/A	N/A	No data
07/02	1.7E+00	-1.7E+00	8.2E-01	
07/03	1.6E+00	-1.8E+00	8.0E-01	
07/04	2.1E+00	-1.8E+00	7.7E-01	
07/05	1.9E+00	-3.4E+00	7.6E-01	
Swarm B, 29/06 - 07/05, ASM-VFM difference				
Day	**Max (nT)**	**Min (nT)**	**Standard deviation (m)**	**Notes**
29/06	1.2E+00	-1.6E+00	3.7E-01	
30/06	N/A	N/A	N/A	No data
07/01	N/A	N/A	N/A	No data
07/02	1.1E+00	-1.4E+00	4.2E-01	
07/03	1.1E+00	-1.3E+00	4.7E-01	
07/04	3.0E+00	-1.7E+00	5.2E-01	
07/05	2.0E+00	-1.8E+00	5.9E-01	

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 (07/05) can be seen in Figure 10 below.

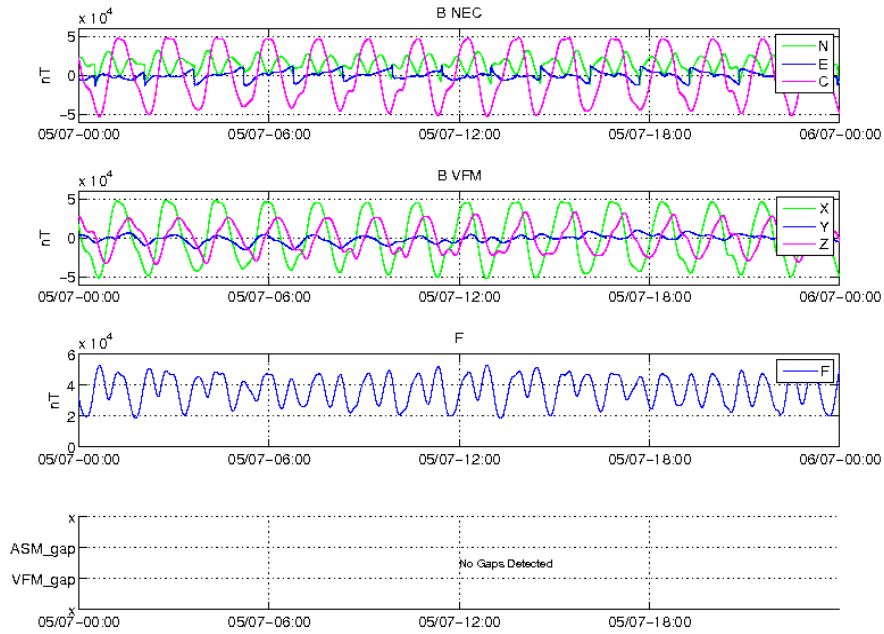

Figure 10: Time series of the geomagnetic field, for 07/05, S/C A. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM, and location of gaps (if any).

3.3.4.2 Swarm B

An example of representative magnetic field time series for S/C B (07/05) can be seen in Figure 11 below.

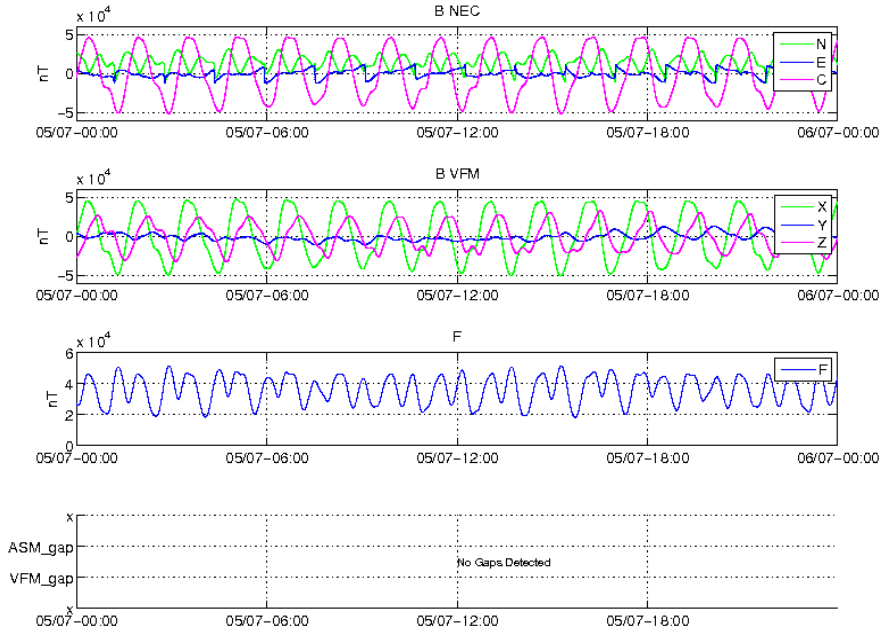

Figure 11: Time series of the geomagnetic field for 07/05, S/C B. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM, and location of gaps (if any).

3.3.4.3 Swarm C

An example of magnetic field time series for S/C C (07/05) can be seen in Figure 12.

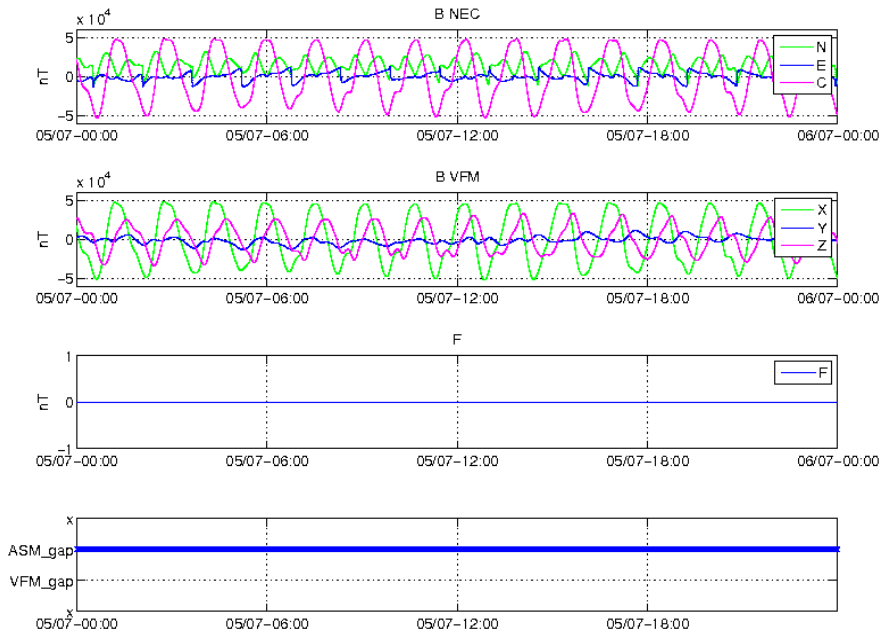

Figure 12: Time series of the geomagnetic field for 07/05, S/C C. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM (no data here because ASM it is off) and location of gaps.

3.3.5 VFM-ASM anomaly

3.3.5.1 Swarm A

The daily peak-to-peak difference around the week stays within [-2, 2] nT with a few spikes not exceeding 1nT and one spikes of about 3nT on 07/05. Below two example plots follows of such differences: 29/06 (Figure 13), and 05/07 (Figure 14).

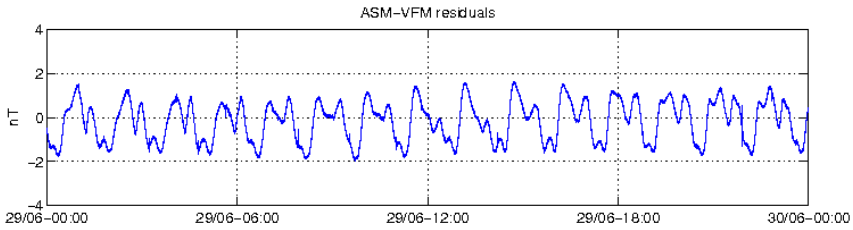

Figure 13: ASM-VFM residuals for S/C A, 29/06.

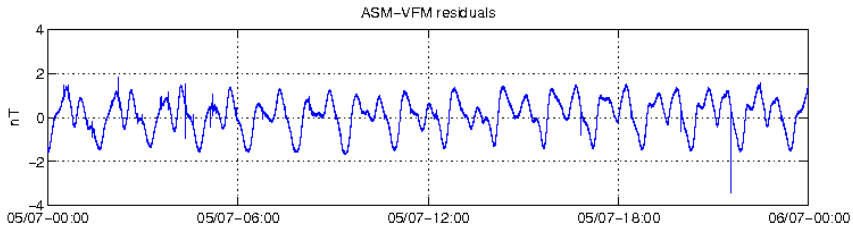

Figure 14: ASM-VFM residuals for S/C A, 05/07.

3.3.5.2 Swarm B

The daily peak-to-peak difference around the week is, on average: [-1.7, 1.5] nT, with a few spikes not exceeding 2 nT and one spike of 4nT on 07/04. Below two example plots follows of such differences: 29/06 (Figure 15), and 05/07 (Figure 16).

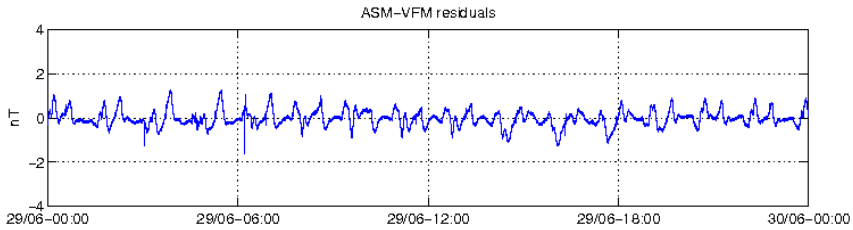

Figure 15: ASM-**VFM** residuals for S/C B, 29/06.

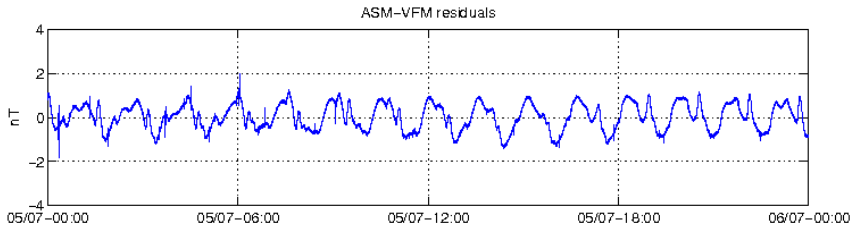

Figure 16: ASM-VFM residuals for S/C B, 05/07.

3.3.5.3 Swarm C

No data because ASM is switched off.

3.3.6 B_{NEC} vs Chaos4plus model residuals

Figure 17, Figure 19 and Figure 21 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 18, Figure 20 and Figure 22 shows, from top to bottom, the time series on 29/06 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.

3.3.6.1 Swarm A

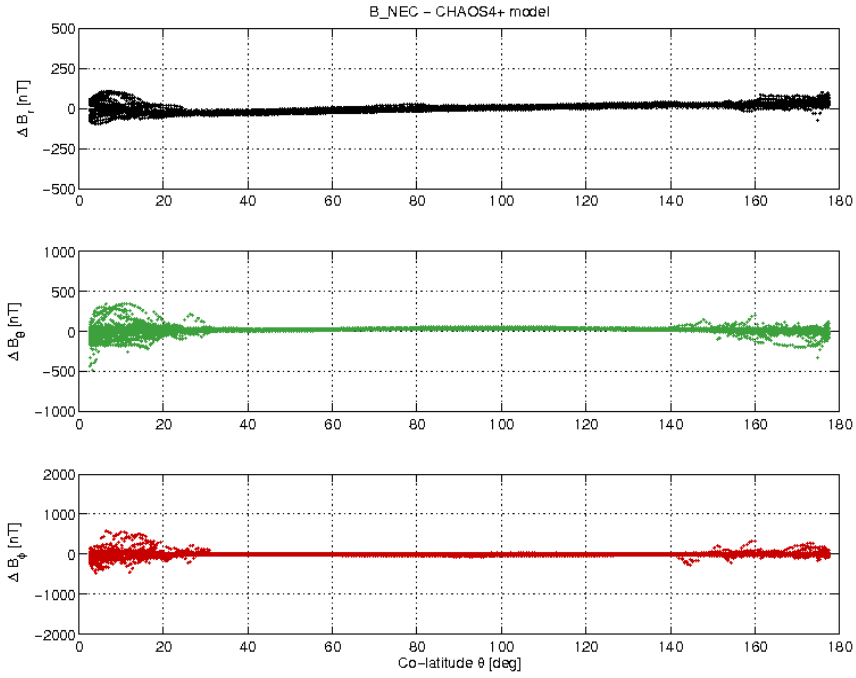

Figure 17: Swarm A day 29/06 B_NEC - B_Chaos vs colatitude.

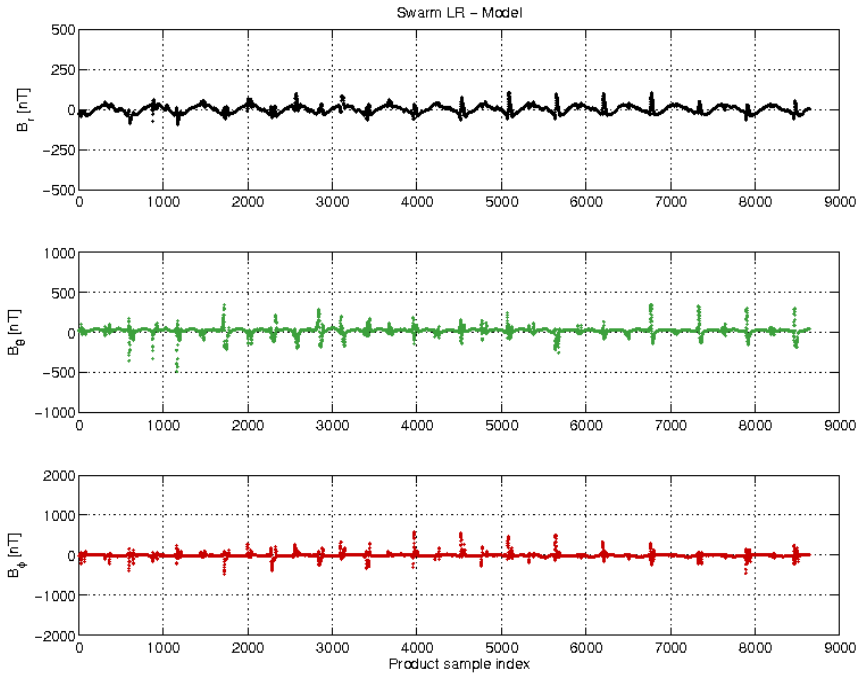

Figure 18: Swarm A day 29/06: time series of B_NEC – B_Chaos residuals.

3.3.6.2 Swarm B

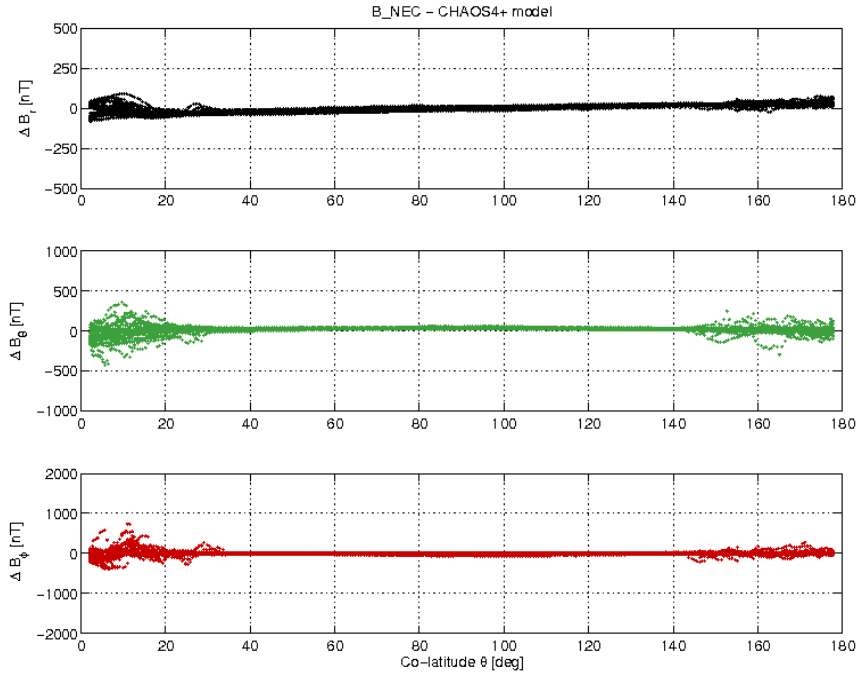

Figure 19 Swarm B day 29/06 B_NEC - B_Chaos difference vs colatitude.

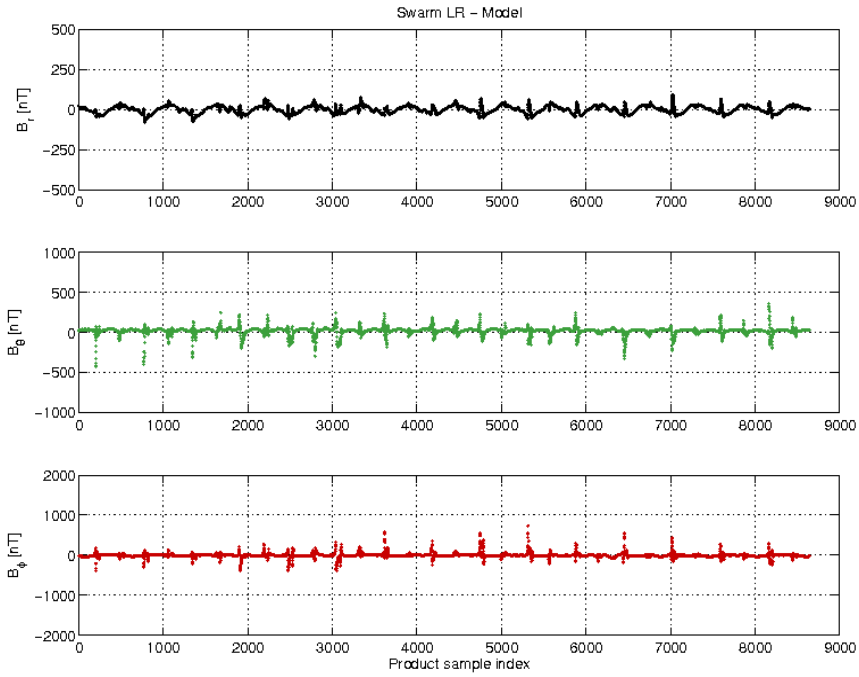

Figure 20 Swarm B day 29/06 time series of B_NEC – B_Chaos residuals.

3.3.6.3 Swarm C

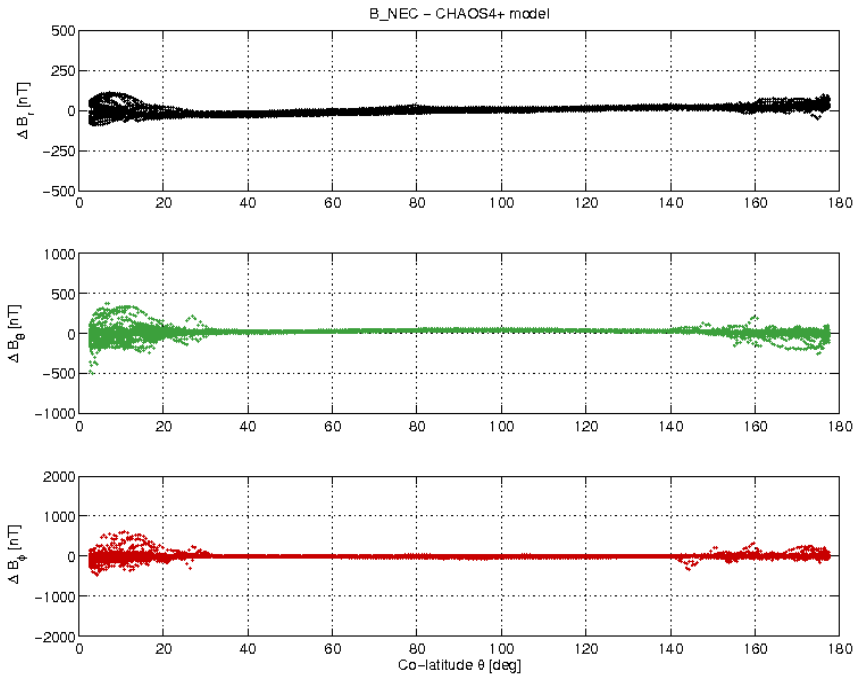

Figure 21 Swarm C day 29/06 B_NEC - B_Chaos difference vs colatitude.

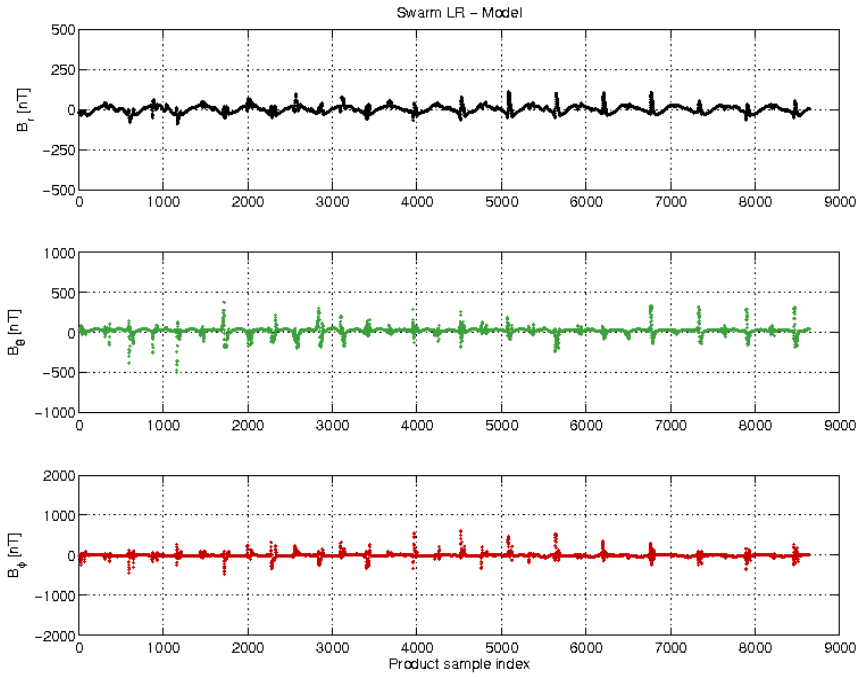

Figure 22 Swarm C day 29/06 time series of B_NEC – B_Chaos residuals.

4. ON-DEMAND ANALYSIS

4.1 Standard deviation of $B_{NEC} - B_{chaos}$ as a proxy for geomagnetic activity

In Figure 23 the time series of the daily standard deviations of the residuals $\mathbf{B_{NEC} - B_{chaos}}$ are shown for the second half of June 2015, in coloured curves which follows the legend on the right for the different S/C and components. The black curve shows the Dst index for the same time period.

A clear correlation is observed on 22/06 between the onset of a geomagnetic storm (sharp Dst decrease), and an increase of the residuals standard deviation, in all components and S/C. This effect is expected, as already explained in the two previous reports, because the Chaos model does not account for the ring current variations and other magnetospheric contributions to the magnetic field. Nevertheless, the correlation is impressive and we mean to refine such kind of analysis with the aim of using the standard deviation of the residuals as a diagnostic parameter, to be compared with geomagnetic activity proxies: if an increase of the standard deviation is not associated to geomagnetic events we could deal with instrumental/data processing issues to be addressed.

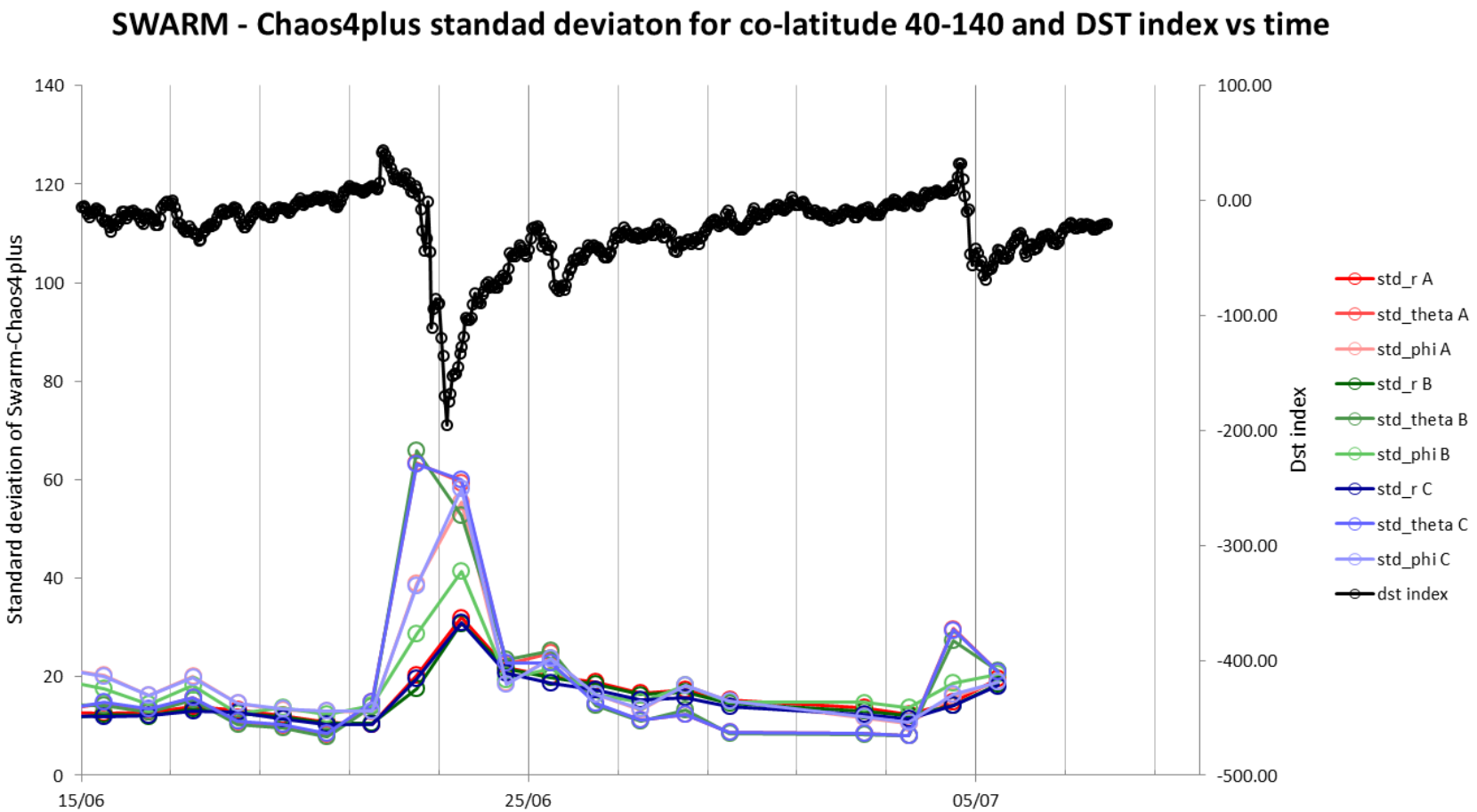

Figure 23: Dst index (black) and St. dev. of the B_{NEC} - B_{Chaos} residuals (curves in different colors for different S/C and components following the legend on the right), during the second half of June 2015.

End of Document