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IDEAS+ Swarm Weekly Report 2015/22: 2015/05/25 - 2015/05/31

Abstract :

This is the **Instrument Data quality Evaluation and Analysis Service Plus** (IDEAS+) Swarm Weekly report on Swarm products quality, covering the period from 25 to 31 May 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	09 Jun 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 2.4.

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 1.14p1
- 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 0009, ADF 0101
- MPPF-CVQ v.2.14

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

TII status. No further updates for this week.

2.2 Plan for operational processor updates

L1B: the cross-verification of PLASMA is on-going, but some issues in the TII parameters are causing some delay. The changes applied to the LP quality flags, has worsened the cross-verification results. Recently, when processing the non-regression scenarios IS01 and IS02 (nominal production for S/C A and B 13/04/2015) proposed by I. Coco **Error! Reference source not found.**, the MAGNET processor has failed. The problem seems to be located in a cubic spline interpolation during the ASM processing. All these issues are under investigation.

L2-Cat2: FAC and IBI have been put into operation the 14/5, basing on uncorrected MAG data whilst TEC have been put in operation the 8/6. The validation of EEF is still on-going.

2.3 Quality Working Group and Cal/Val Coordination

Coordination is in place for organizing the 6th Swarm Data Quality Workshop in Paris (hosted by IPGP) in late 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.

[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).*

v. To better quantify (from models) potential plasma-related effects. Link to MAGx_HR.

vi. Involvement of EFI-TII team.

The next task force meeting is scheduled for **2-3 July 2015**.

2.4 Summary of observations for 2015, Week 22 (25/05 - 31/05)

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

- **Two of events of attitude rejection** is observed for S/C A (27/05), and S/C B (26/05), due to simultaneous occurrence of BBOs on two cameras and invalid measurement on another one (SW-IDEAS-72).
- **Several gaps in MAGx_CA_1B products (each of them lasts 9 seconds)** throughout the week. These seem not to be associated to gaps in telemetry. Monitoring on-going.

3. ROUTINE QUALITY CONTROL

3.1 Gaps analysis

- Gaps in in MAGA_CA_1B on S/C A and B during whole week 22.

3.2 Orbit and Attitude Products

The following events have to be reported:

Observation ID	Description	Affected parameter	Sect. of Obs. Description	Sect. of Obs. Analysis
SW-IDEAS-74	OBS_ROUTINE: 2015, week 22 (25/05 - 31/05), STR S/C A and B out of range.	STRAATT_1B STRASCI_1A STRBATT_1B STRBSCI_1A	3.2.2	3.2.2
SW-IDEAS-63	OBS_ROUTINE: MAGx_CA_1B gaps	MAGx_CA_1B	3.1	3.1

Table 1: List of events related to attitude and orbit products to be reported in the monitoring for 2015, Week 22: 25/05 - 31/05.

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.

Swarm A, 25/05 - 31/05, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
25/05	0.22	-7.2 (Y)	6.4	1.31	
26/05	0.11	-7.5	6.1	1.13	
27/05	0.12	-8.5	7.7 (Y)	1.38	
28/05	0.13	-7.3	7.2	1.34	
29/05	0.2	-8.7	12.1	1.38	
30/05	0.16	-6.7	7.8	1.38	
31/05	0.14	-7.7	7.8	1.23	
Swarm B, 25/05 - 31/05, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
25/05	0.21	-5.7	8	1.16	
26/05	0.18	-5.8	7.1	1.12	
27/05	0.13	-6.5	7.1	1.31	
28/05	0.07	-6.2 (Y)	7.8	1.27	
29/05	0.23	-14.5	7.6 (X)	1.41	
30/05	0.1	-6.6	7.2	1.34	
31/05	0.11	-7	6.7	1.13	
Swarm C, 25/05 - 31/05, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
25/05	0.21	-5.9	6.6 (X)	1.24	
26/05	0.13	-5.5	5.8	1.1	
27/05	0.13	-6.6	8.1	1.36	
28/05	0.11	-6.6	6.3	1.3	
29/05	0.24	-7.3	7.4	1.34	
30/05	0.18	-6.7	6.5	1.32	
31/05	0.15	-7.3	5.6	1.2	

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.

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 (25/05, Figure 1) in the middle (28/05, Figure 2) and at the end (31/05, Figure

3). From top to bottom the plots show: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two. The values of position are given in [km] and the difference between both solutions is given in [m].

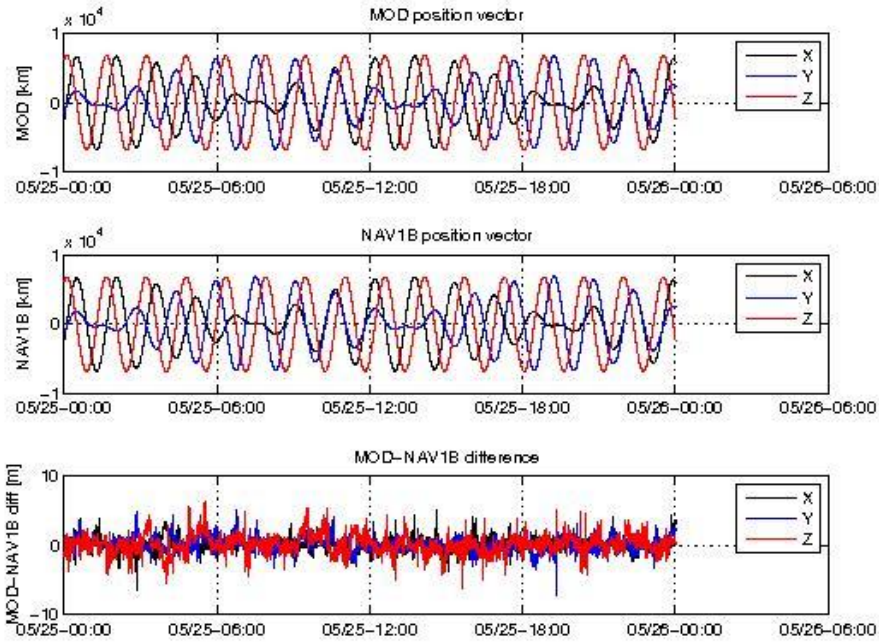

Figure 1: Difference MOD-GPSNAV, S/C A, 25/05. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

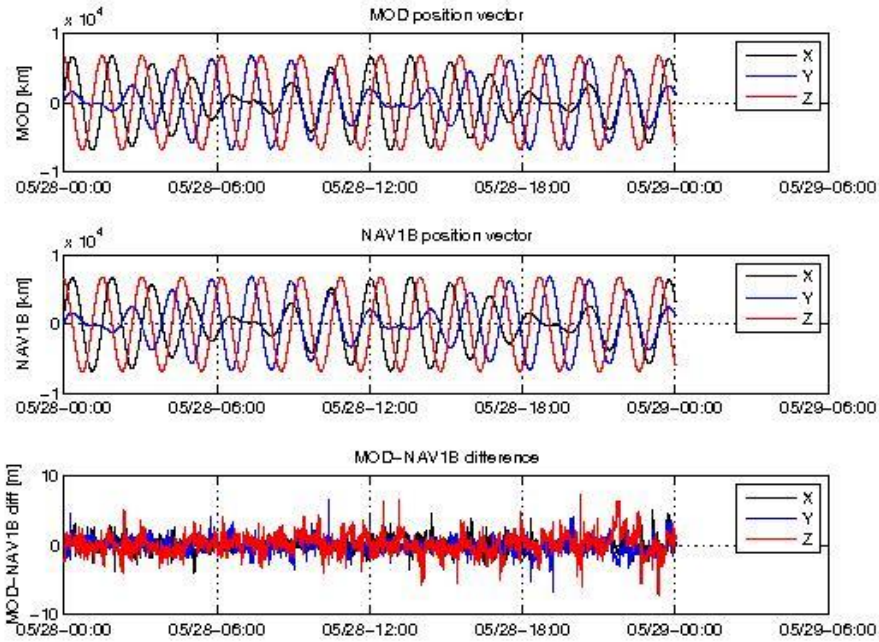

Figure 2: Difference MOD-GPSNAV, S/C A, 28/05. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

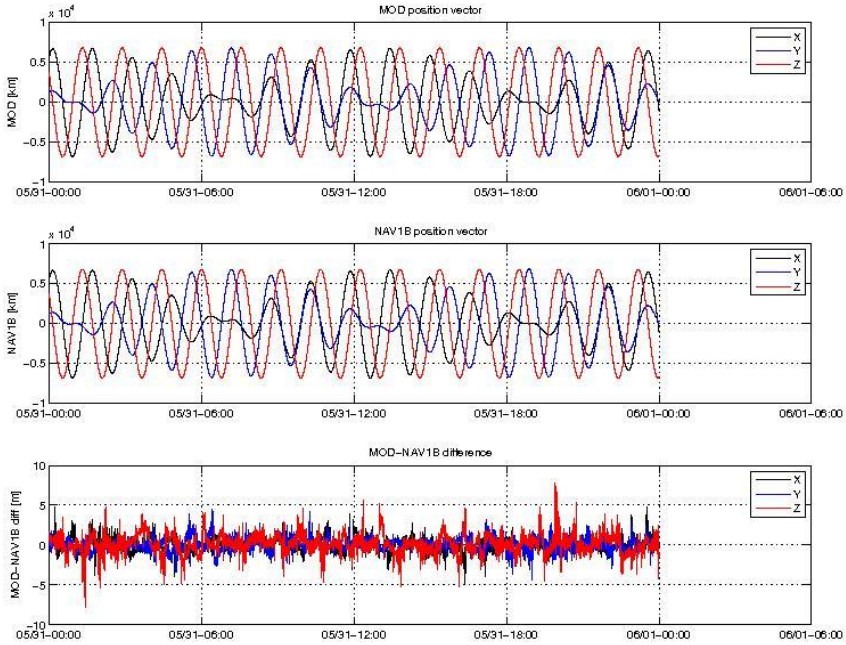

Figure 3: Difference MOD-GPSNAV, S/C A, 31/05. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

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 (25/05, Figure 4), in the middle (28/05, Figure 5), and at end of the week (31/05, Figure 6). From top to bottom the plots show: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two. The values of position are given in [km] and the difference between both solutions is given in [m].

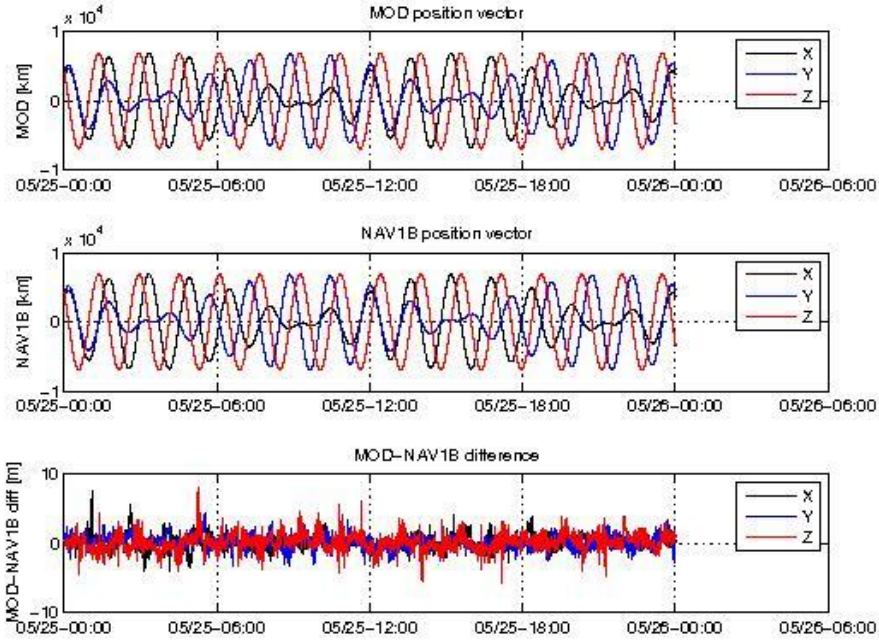

Figure 4: Difference MOD-GPSNAV, S/C B, 25/05. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

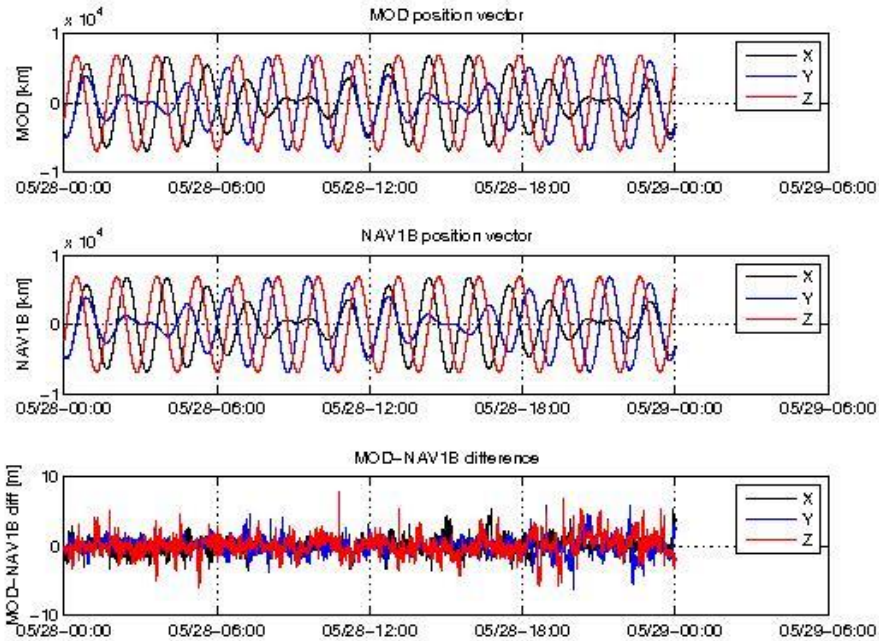

Figure 5: Difference MOD-GPSNAV, S/C B, 28/05. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

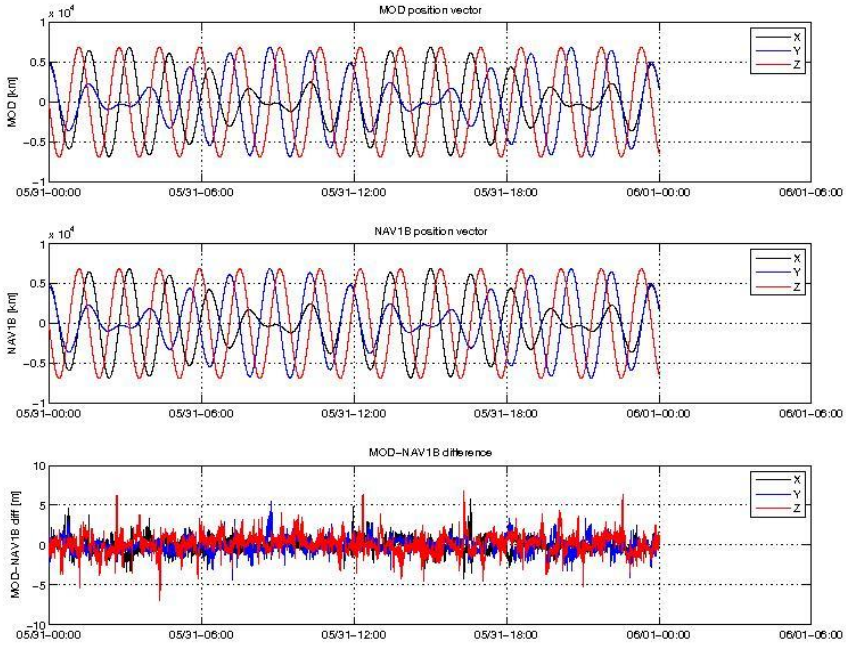

Figure 6: Difference MOD-GPSNAV, S/C B, 31/05. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

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 (25/05, Figure 7), in the middle (28/05, Figure 8) and at the end (31/05, Figure 9). From top to bottom the plots show: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two. The values of position are given in [km] and the difference between both solutions is given in [m]

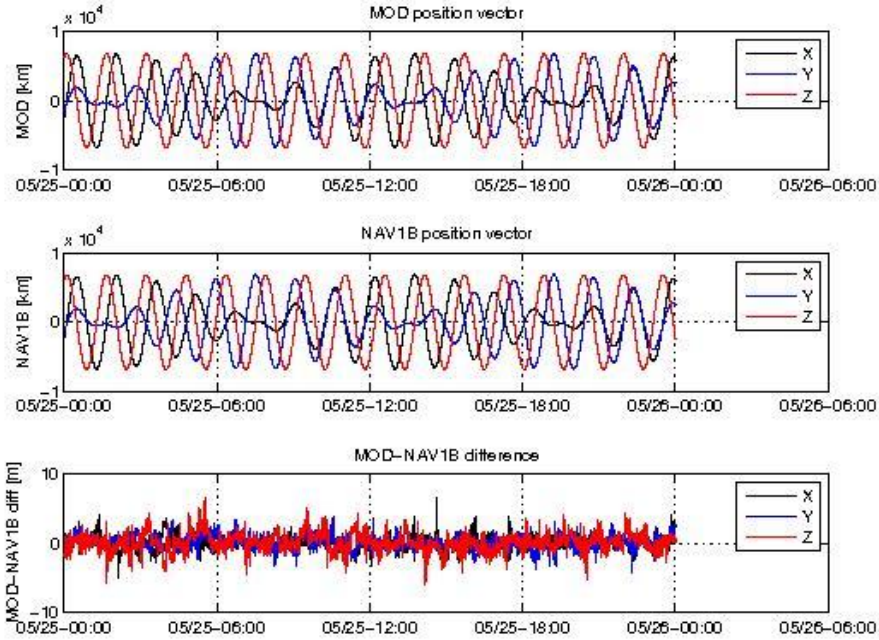

Figure 7: Difference MOD-GPSNAV, S/C C, 25/05. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

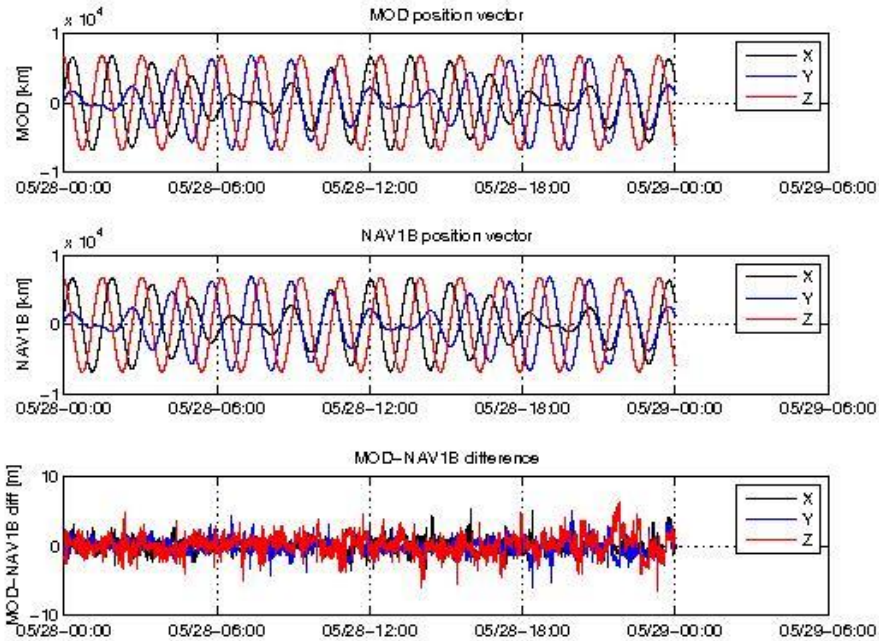

Figure 8: Difference MOD-GPSNAV, S/C C, 28/05. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

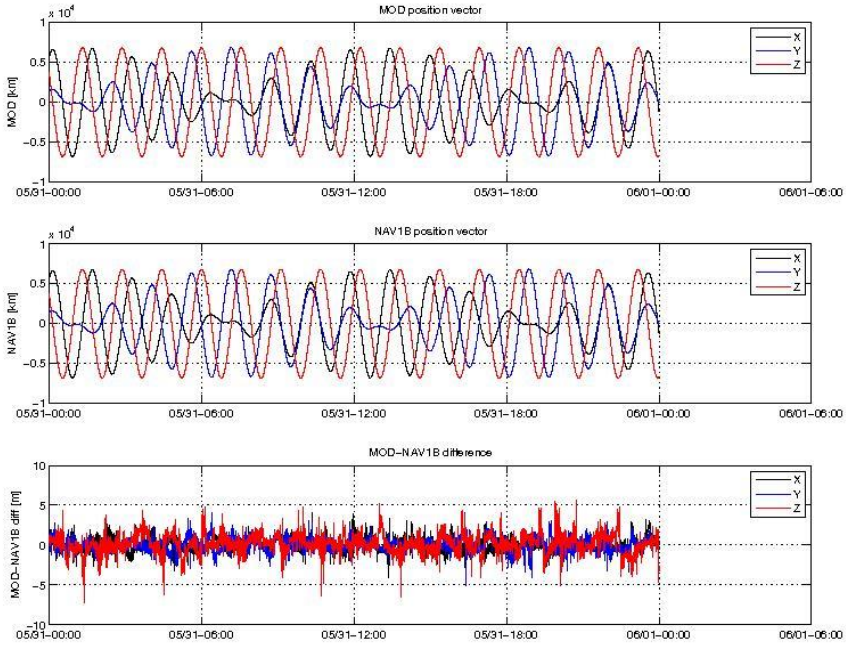

Figure 9: Difference MOD-GPSNAV, S/C C, 31/05. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

3.2.2 Attitude observations

3.2.2.1 Swarm A

- SW-IDEAS-74: We observe an an interval of rejected attitudes for S/C A on 27/05 (Flags_q=255). The reason for such rejection is the simultaneous occurrence of BBOs on CHU 1, 2 and 3. See Table 3 below for details.

Start time	Stop time	Value	Length
27/05/2015 18:32:28	27/05/2015 18:32:33	255	6

Table 3 Attitudes out-of-range on S/C A, due to BBOs and invalid measurements, week 22.

3.2.2.2 Swarm B

- SW-IDEAS-74: We observe an an interval of rejected attitudes for S/C B on 26/05 (Flags_q=255). The reason for such rejection is the simultaneous occurrence of BBOs on CHU 3 and invalid measurements on CHU 1 and 2. See Table 4 below for details.

Start time	Stop time	Value	Length
26/05/2015 08:24:03	26/05/2015 08:24:06	255	4

Table 4 Attitudes out-of-range on S/C B, due to BBOs and invalid measurements, week 22.

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. The parameters are visually inspected and an alert is raised if the behaviour goes out of threshold ([-30; 50] deg for the ASM temperature)

- **VFM instrument monitoring:** VFM sensor temperatures. The VFM instrument parameters important for monitoring the instrument health are the VFM sensor temperatures: T_CDC, T_CSC and T_EU. The parameters are visually inspected and an alert is raised if their behaviour goes out of threshold (50 deg for T_CSC and T_EU; $T\_CDC(t_{i+1}) - T\_CDC(t_i) < 1.5$ deg)

- Visual inspection of daily time series of magnetic field intensity F, $\mathbf{B_{NEC}}$ and $\mathbf{B_{VFM}}$. 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 **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.
- TCF.VFM parameters monitoring (VFM calibration parameters): series of biases, scales, non-orthogonality factors and RMS. **This check is performed on monthly basis.**
- **Comparison of magnetic data ($\mathbf{B_{NEC}}$) with a model (Chaos4plus)**; when persistent deviations from +/- 50 nT in +/- 55 deg latitude sector or from +/- 150 nT above |55| latitude are observed, an alert is raised.

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

For S/C Alpha and Bravo the temperature and quartz frequency behaved as expected.

3.3.2 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.

3.3.3 Magnetic time series visual inspection

3.3.3.1 Swarm A

An example of representative magnetic field time series for S/C A (31/05) can be seen in Figure 10 below.

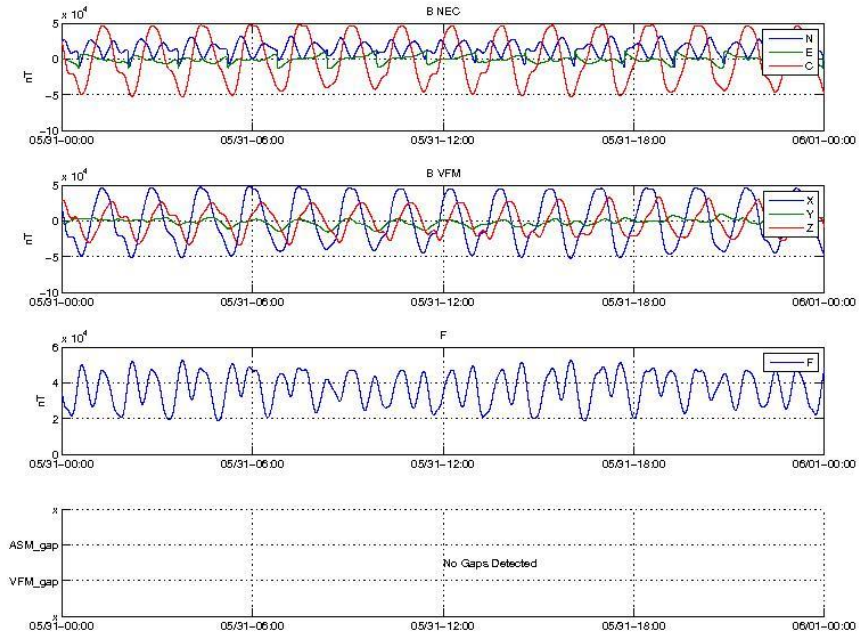

Figure 10: Time series of the geomagnetic field, for 31/05, S/C A. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM, and location of gaps (if any).

3.3.3.2 Swarm B

An example of representative magnetic field time series for S/C B (31/05) can be seen in Figure 11 below.

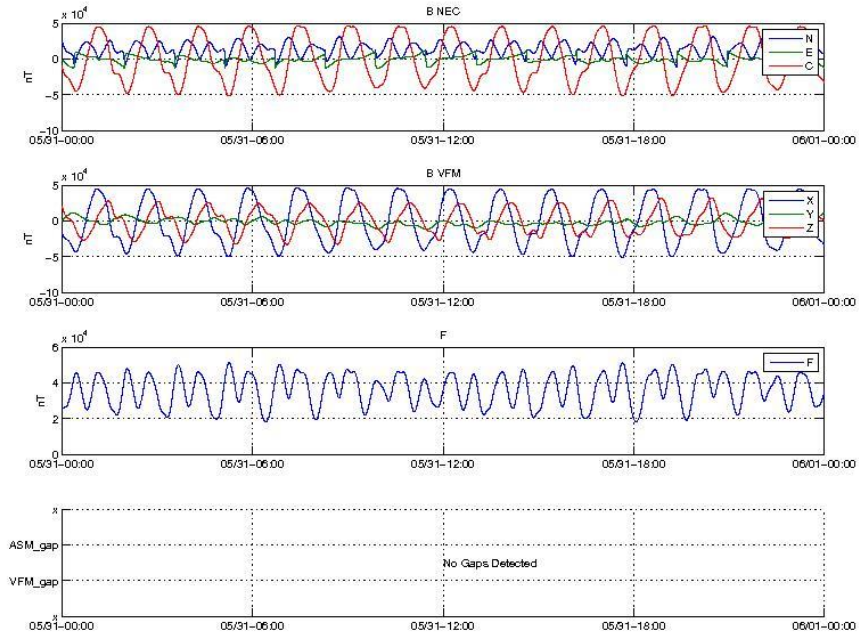

Figure 11: Time series of the geomagnetic field for 31/05, S/C B. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM, and location of gaps (if any).

3.3.3.3 Swarm C

An example of magnetic field time series for S/C C (31/05) can be seen in Figure 12.

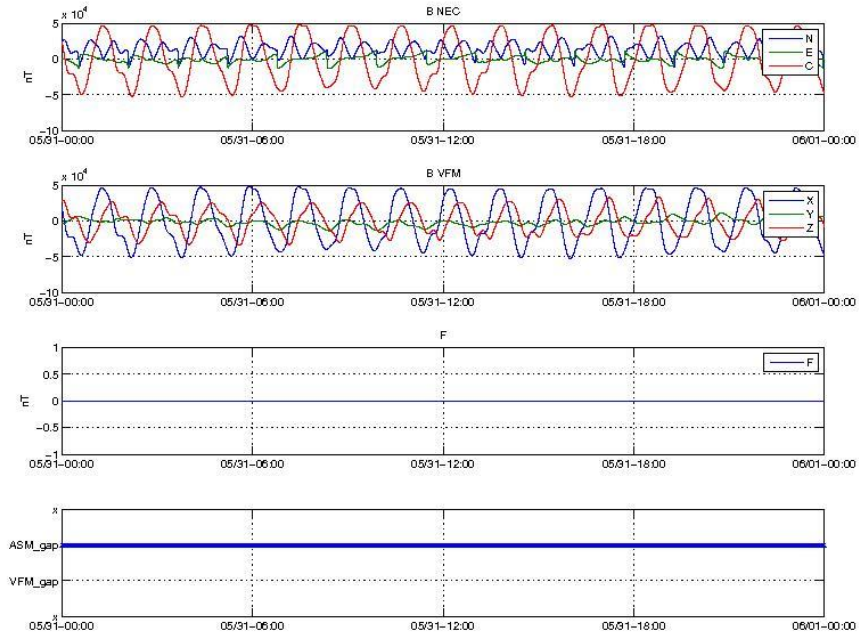

Figure 12: Time series of the geomagnetic field for 31/05, S/C C. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM (no data here because ASM it is off) and location of gaps.

3.3.4 VFM-ASM anomaly

3.3.4.1 Swarm A

The daily peak-to-peak difference for the only available day during current week stays within [-2.7, +1.8] nT with a few spikes not exceeding 2nT.

Below two example plots follows of such differences: 25/05 (Figure 13), and 31/05 (Figure 14). From top to bottom the plots show: The VFM module, the ASM module, the difference ASM-VFM

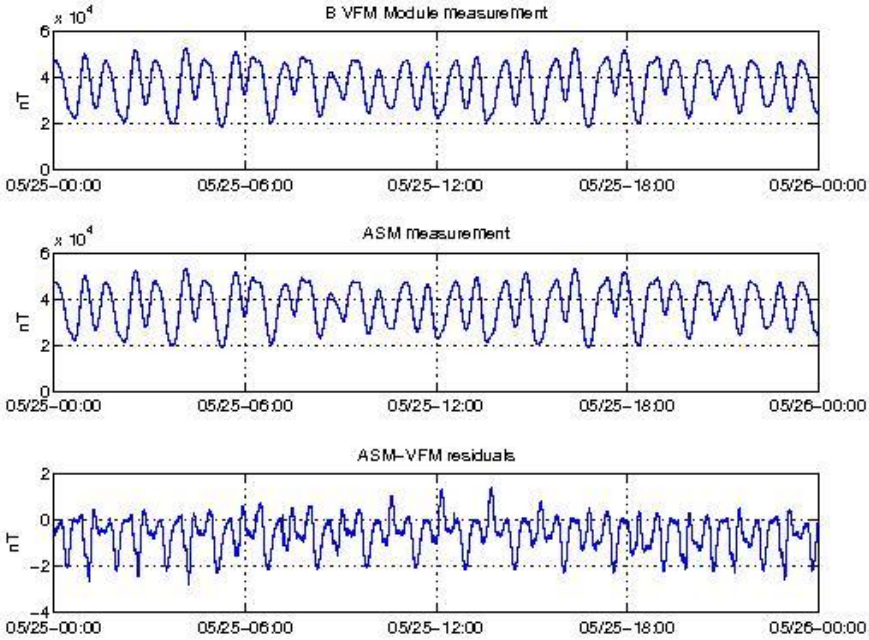

Figure 13: VFM module, ASM module and ASM-VFM residuals for S/C A, 25/05.

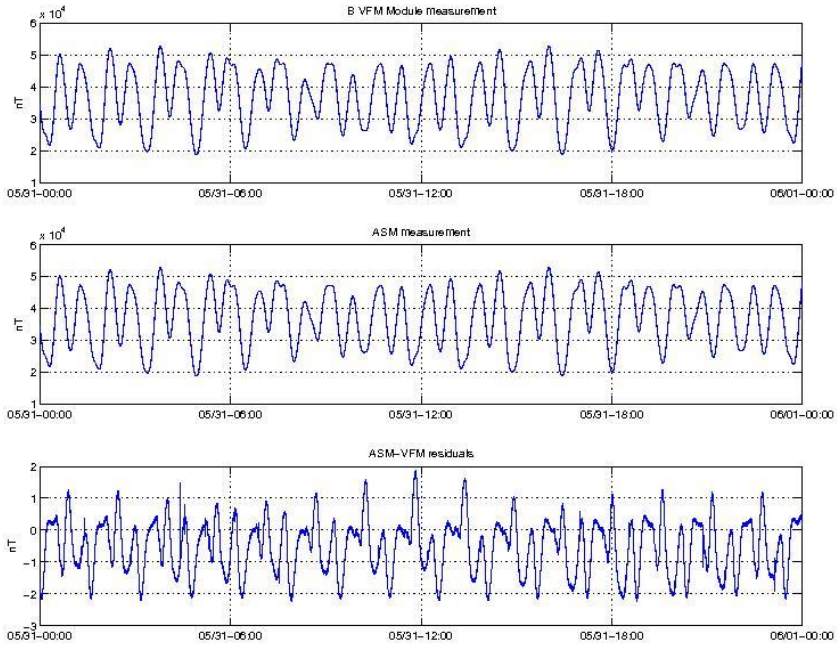

Figure 14: VFM module, ASM module and ASM-VFM residuals for S/C A, 31/05.

3.3.4.2 Swarm B

The daily peak-to-peak difference around the week is, on average: [-1.2, 1.2] nT, with a few spikes not exceeding 1 nT and one spike of 5nT on 28/05.

Below two example plots follows of such differences: 25/05 (Figure 15), and 31/05 (Figure 16). From top to bottom the plots show: The VFM module, the ASM module, the difference ASM-VFM.

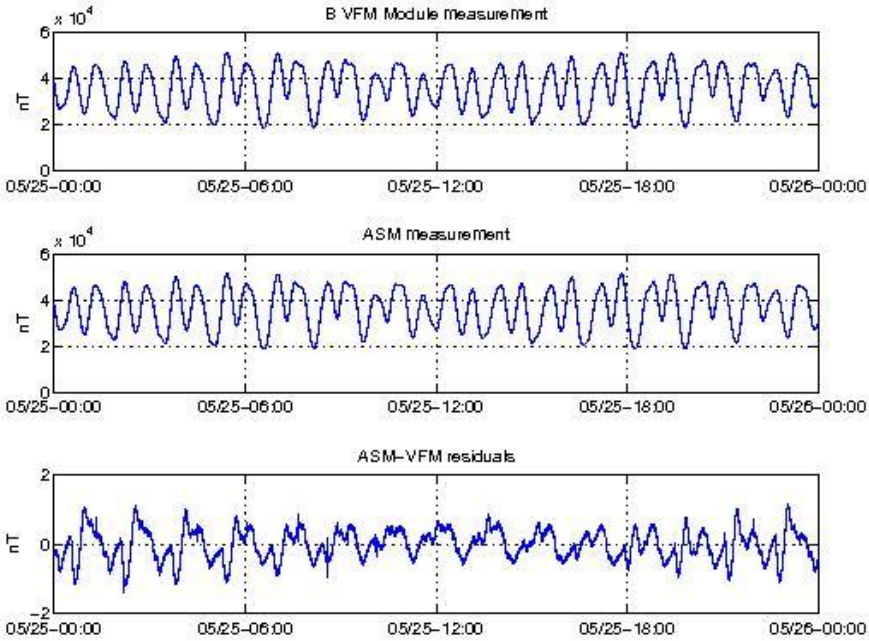

Figure 15: VFM module, ASM module and ASM-VFM residuals for S/C B, 25/05.

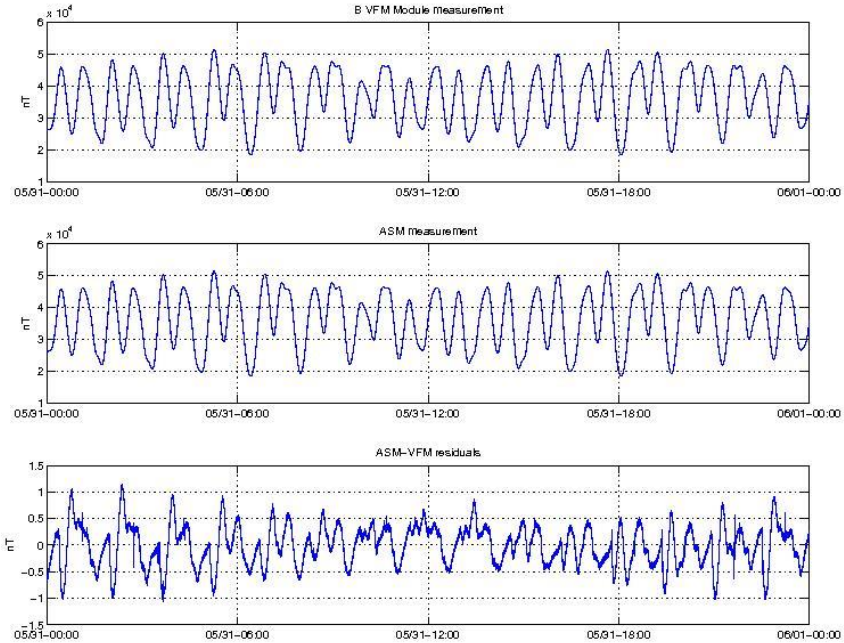

Figure 16: VFM module, ASM module and ASM-VFM residuals for S/C B, 31/05.

3.3.4.3 Swarm C

No data because ASM is switched off.

3.3.5 B_{NEC} vs Chaos4plus model residuals

Figure 17, Figure 19 and Figure 21 refer to 25/5, S/C A,B and C respectively and show, from top to bottom: (1) components of B field in NEC frame, (2) components of B field from CHAOS4plus model (3) field residuals $dB=B_{NEC} - B_{Chaos}$ (all versus co-latitude in degrees).

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 25/05, S/C A, B and C respectively, of: (1-2-3) residuals of B_{NEC}-B_{CHAOS} by components (4) residuals of B_N-B^{θ}_{CHAOS} in +/-200nT range, related to Swarm Alpha, Bravo and Charlie respectively.

The component most affected by residual spikes and variations is B_theta_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

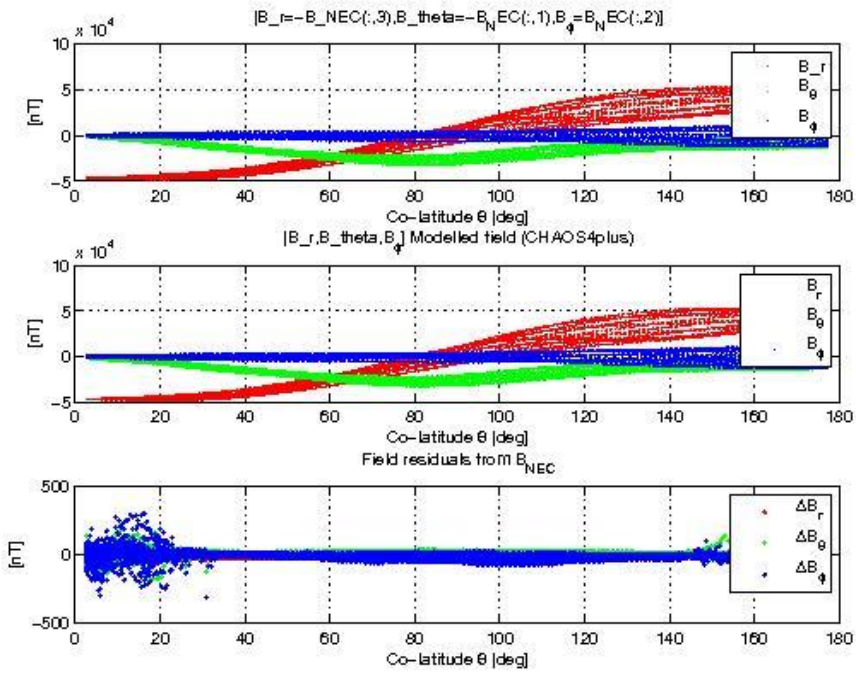

Figure 17: Swarm A day 25/05 B_NEC and B_Chaos vs colatitude.

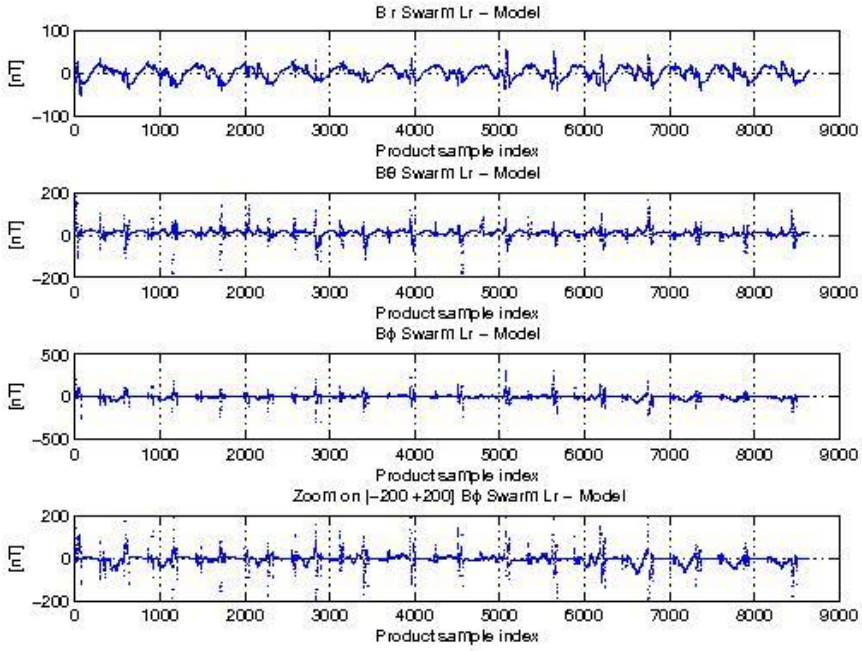

Figure 18: Swarm A day 25/05: time series of B_NEC – B_Chaos residuals.

3.3.5.2 Swarm B

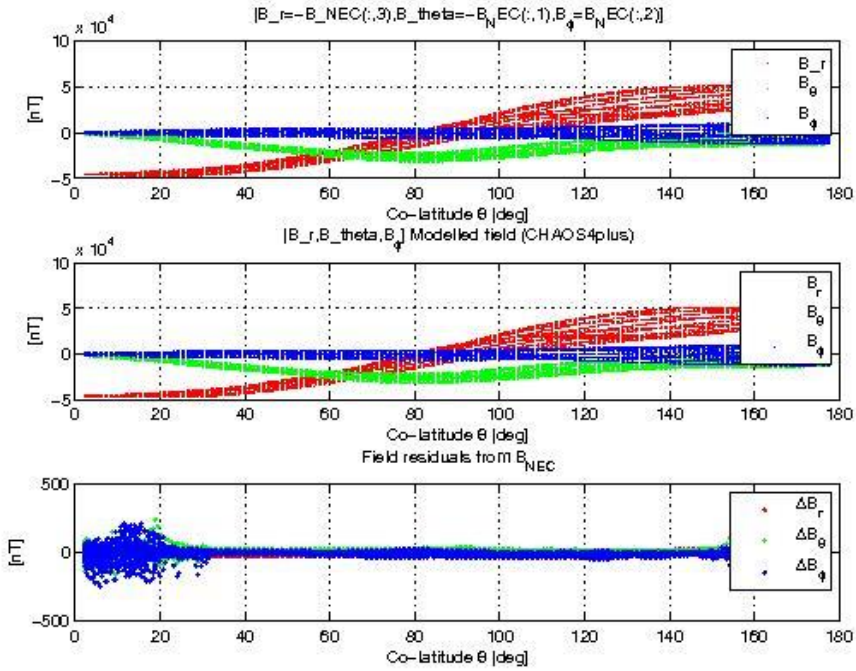

Figure 19 Swarm B day 25/05 B_NEC and B_Chaos vs colatitude.

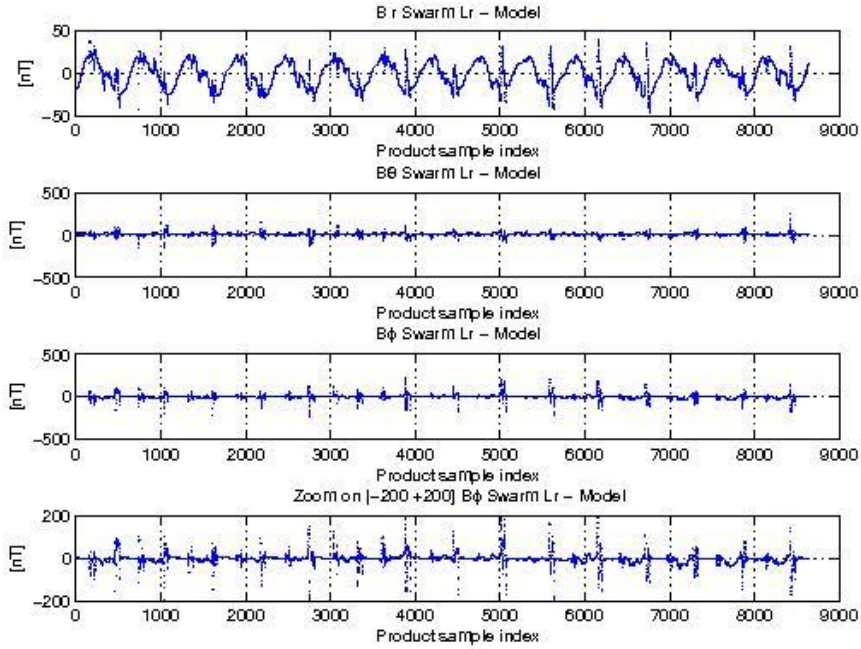

Figure 20 Swarm B day 25/05 time series of B_NEC – B_Chaos residuals.

3.3.5.3 Swarm C

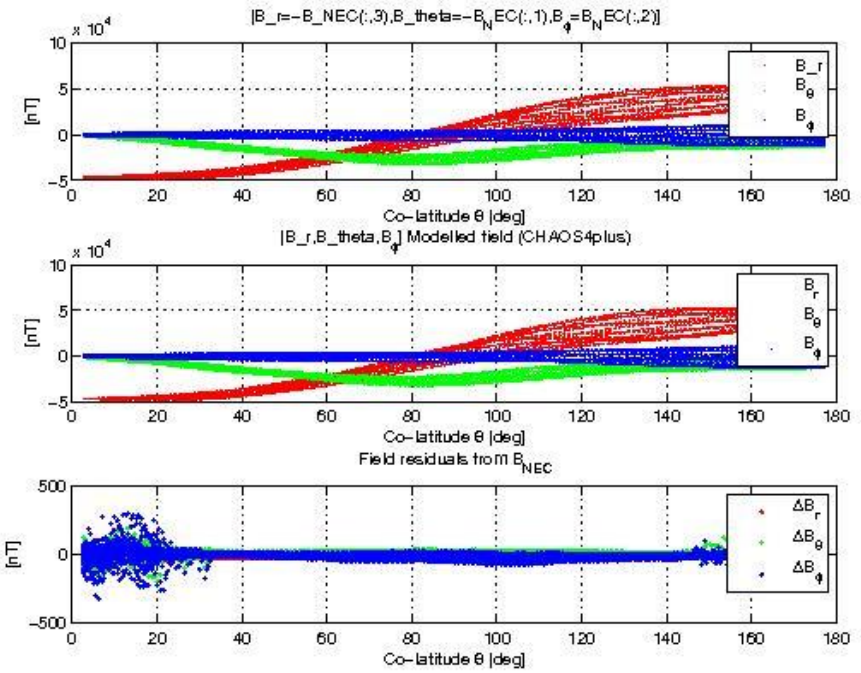

Figure 21 Swarm C day 25/05 B_NEC and B_Chaos vs colatitude.

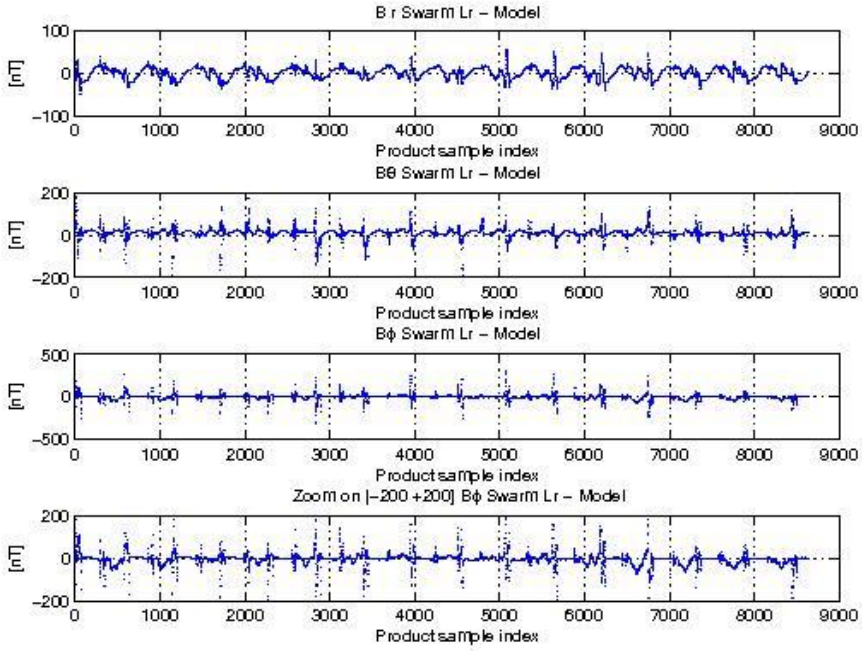

Figure 22 Swarm C day 25/05 time series of B_NEC – B_Chaos residuals.

4. ON-DEMAND ANALYSIS

Nothing to report.

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