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IDEAS+ Swarm Weekly Report 2015/13: 2015/03/23 - 2015/03/29

Abstract : This is the **Instrument Data quality Evaluation and Analysis Service Plus** (IDEAS+) Swarm Weekly report on Swarm products quality, covering the period from 23 to 29 March 2015.

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

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

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

Serco Italia Spa
Via Sciadonna 24/26, 00040, Frascati, Italy
Tel: +39 06 98354400 Fax: +39 06 9419426
www.serco.com

TABLE OF CONTENTS

Contents

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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	08 Apr 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 3.14.01, 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 0009, ADF 0101
- MPPF-CVQ v.2.12p1

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 Level 1b Processor Algorithms, SW-RS-DSC-SY-0002, Issue 6.9

[RD.15] SWARM L1B 03.15 Validation Report, OSMV-OPMT-SRCO-RP-15-3385, Issue 1.3

2. SUMMARY OF THE OBSERVATIONS

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

- **TII Image anomaly.** After the execution of a second aggressive scrubbing on Charlie, all the three S/C are now in active state waiting for results evaluation by the Calgary team. A combination of yaw and pitch manoeuvres on Swarm Alpha will be soon planned for investigating the effects of a less intense sensor exposure to the dominant plasma fluxes. Next ARB is scheduled for 9/4.

- **LP sweep mode investigations:** During EFI teleconferences on past weeks, an activity discussed at the DQW in Potsdam has been exhumed. The effect of the sweep mode activation on the S/C potential and electron temperature should be better characterized, through several cycles of more severe sweep configurations: e.g., [+5, -5] V for several orbits. A proposal will be soon prepared by IRF along with proper telecommands, and the activity will be scheduled with Calgary and FOS, because a coordinated analysis with TII results is needed and, for that purpose, the activity should be carried on when the TII images show good quality (e.g., Swarm A after a scrubbing cycle followed by a ready state interval).

2.2 Plan for operational processor updates

L1BOP 3.15 has been put into operation on March 23th. The data quality with the new processor has been quickly assessed and it is satisfactory ([RD.15]).

The PDGS team is proceeding with the recovery of the failed production due to the bug in L1BOP 3.14, and the generation of the Swarm C magnetic production lost from 6th November (when ASM has fallen down).

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.

According to the last coordination meeting within the MAGNET QWG (22/01/2015) the following decisions have been taken:

- With the data provided by DTU/ESL, further analysis can be performed by industry (ADS, DTU-MI), other scientific groups (e.g. Richard Marchand and Stephan Buchert on plasma induced fields), and of course by ESA. The agreement is - as always - that results will be shared with all others on the Task Force.

- DTU/ESL will further refine the Lesur-Tøffner-Clausen model parametrisation and share a final description of the process (input data, model description, output results and tests) (by mid-February).

- In parallel, GFZ will distribute the Lühr-Michaelis results, and a number of people (e.g. Malcolm Dunlop, Yulia Bogdanova, Arnaud Chulliat, and Patrick Alken) will further support the analysis of these datasets (by mid-February).

- The PDGS will generate the currently VFM missing data on Charlie due to the ASM failure (by end February).

- DTU/ESL will share the final set of corrected data by early March. These corrected data will also contain the dBsun correction, providing the users the possibility to access to uncorrected data.

- The corrected data will be distributed by ESA to all Swarm users (by early April and no later than 20th April). The correction will also be implemented in the OP. Until this is fully validated, it is agreed that the operational processing will continue as nominal without the correction.

- Next Task Force meeting: **9-10 April**. The meeting will be held in ESTEC.

2.4 Summary of observations for 2015, Week 13 (23/03 - 29/03)

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

- **Two GPS loss of sync** observed for S/C B during week 13

- **Several features observed in the MOD-NAV difference:** spikes above 18-20 m are observed almost every day for all S/C (**SW-IDEAS-61**); again we observe at times deviations from the average values lasting several minutes (**SW-IDEAS-34**).

- **Few cases of rejected attitudes** observed on S/C A due to simultaneous occurrence of BBO and invalid measurements (**SW-IDEAS-66**).

3. ROUTINE QUALITY CONTROL

3.1 Gaps analysis

- **GPS sync loss events** on S/C B on 25/03 and 28/03. Details are given in Sect. 3.2.2.2. GPS out-of-sync timestamps are rejected by the Level 1B processor and cause gaps to be present in all the Level 1A products.
- **VFM gaps on**Error! Bookmark not defined. **S/C A 29/03.** A number of short gaps (2 seconds) shall be reported on the following product:
    - SW_OPER_VFMANOM_0__20150329T165250_20150330T070549_0201

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-34	OBS_ROUTINE: large number of spiky features observed in the NAV-MOD difference	Orbits (position and velocity)	3.2.1.1	[RD.10]
SW-IDEAS-40	OBS_ROUTINE: STR out of range - ANOMALOUS CASES	All level 1A and level 1B products	3.2.2.2	[RD.12]
SW-IDEAS-61	OBS_ROUTINE: 02-08/03/2015 huge spikes observed in the MOD-NAV difference	Orbits (position and velocity)	3.2.1.1 3.2.3.1	4.1
SW-IDEAS-66	OBS_ROUTINE: 2015, week 13 (23-29/03), STR S/C A out of range.	STRAATT_1B STRASCI_1A	3.2.1.2	3.2.1.2

Table 1: List of events related to attitude and orbit products to be reported in the monitoring for 2015, Week 13: 23/03 - 29/03.

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 Swarm A

3.2.1.1 Position statistics

In Table 2 one can see the statistics of the differences between MOD and on-board solution positions. 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, 23/03 - 29/03, Position difference					
Day	**Average difference (m)**	**Maximum difference (m)**		**Maximum standard deviation (m)**	**Notes**
23/03	0.08	-6.6	7.3 (Y)	1.29	
24/03	0.13	-8.0	7.5 (Y)	1.38	SW-IDEAS-34 [RD.10]
25/03	0.17	-9.2	8.4	1.78	SW-IDEAS-34 [RD.10]
26/03	0.12	-7.1	7.5	1.41	SW-IDEAS-34 [RD.10]
27/03	0.14	-6.5 (Y)	8.7 (X)	1.31	
28/03	0.13	-6.6	8.2	1.31	
29/03	0.13	-7.7 (X)	8.7	1.32	SW-IDEAS-34 [RD.10]

Table 2: Swarm A, difference between MOD and on-board solution positions. If not specified maximum difference and maximum standard deviation refers to the Z axis.

Below some plot example follows of such differences taken at the beginning of the week (23/03, Figure 1) in the middle (26/03, Figure 2) and at the end (29/03, 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].

In Figure 2, red-circled area, one can see an example of SW-IDEAS-34 anomalous observation occurrence ([RD.10]): the MOD-NAV difference departs from the average value and keeps a higher level for several minutes.

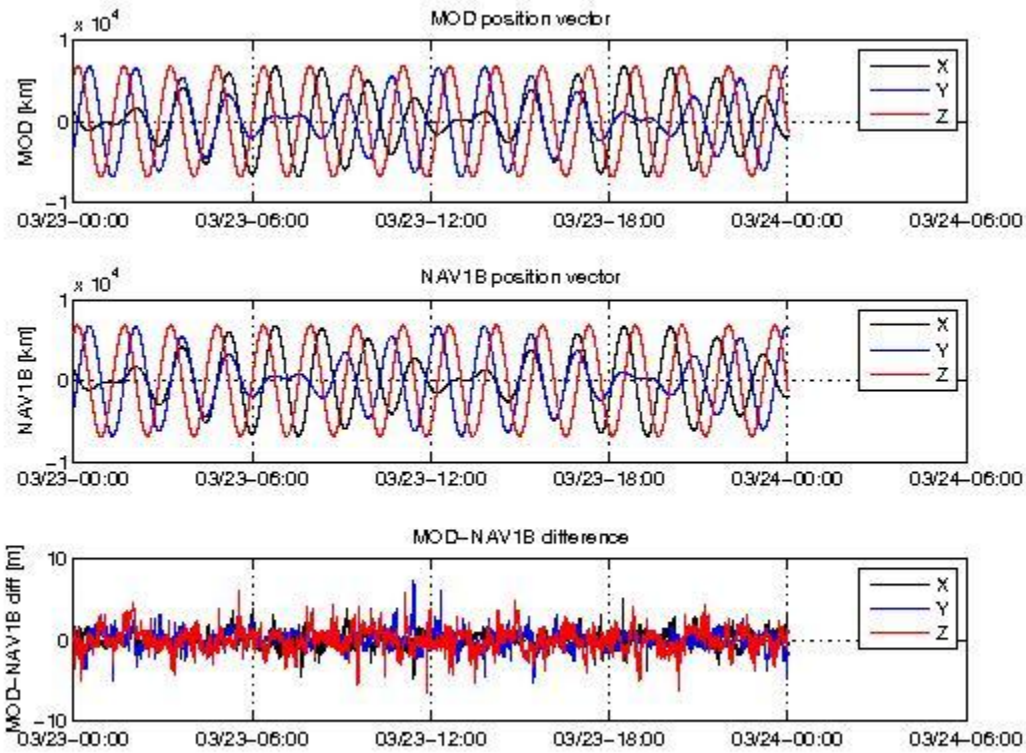

Figure 1: Difference MOD-GPSNAV, S/C A, 23/03. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

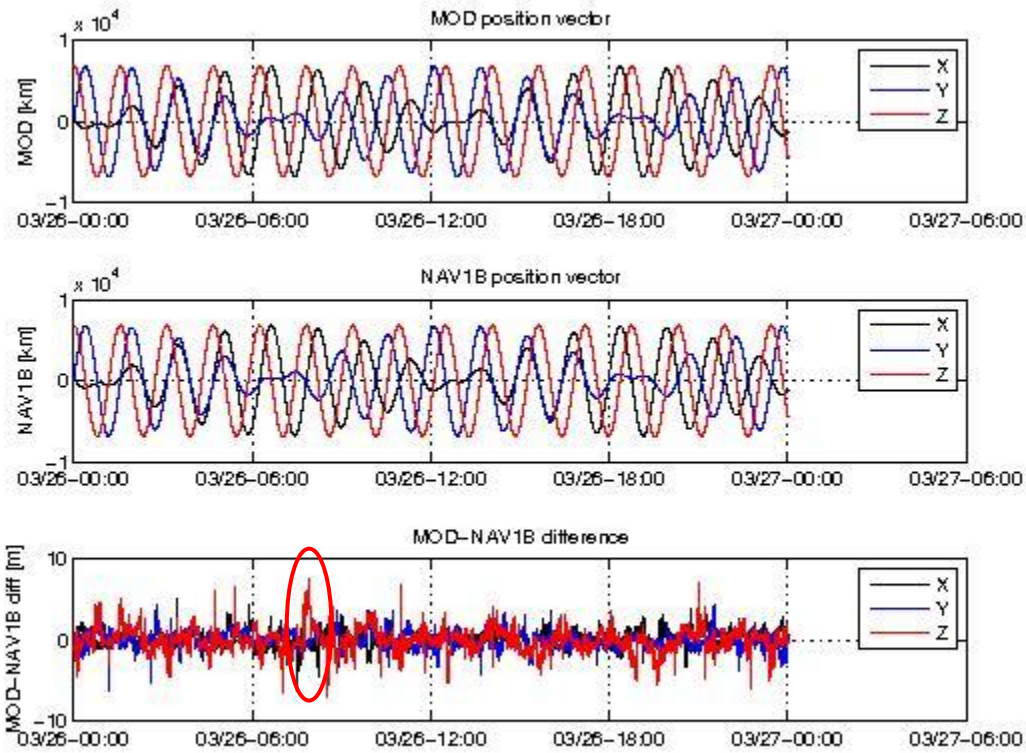

Figure 2: Difference MOD-GPSNAV, S/C A, 26/03. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two. The red circled area shows an occurrence of SW-IDEAS-34 ([RD.10]) anomaly.

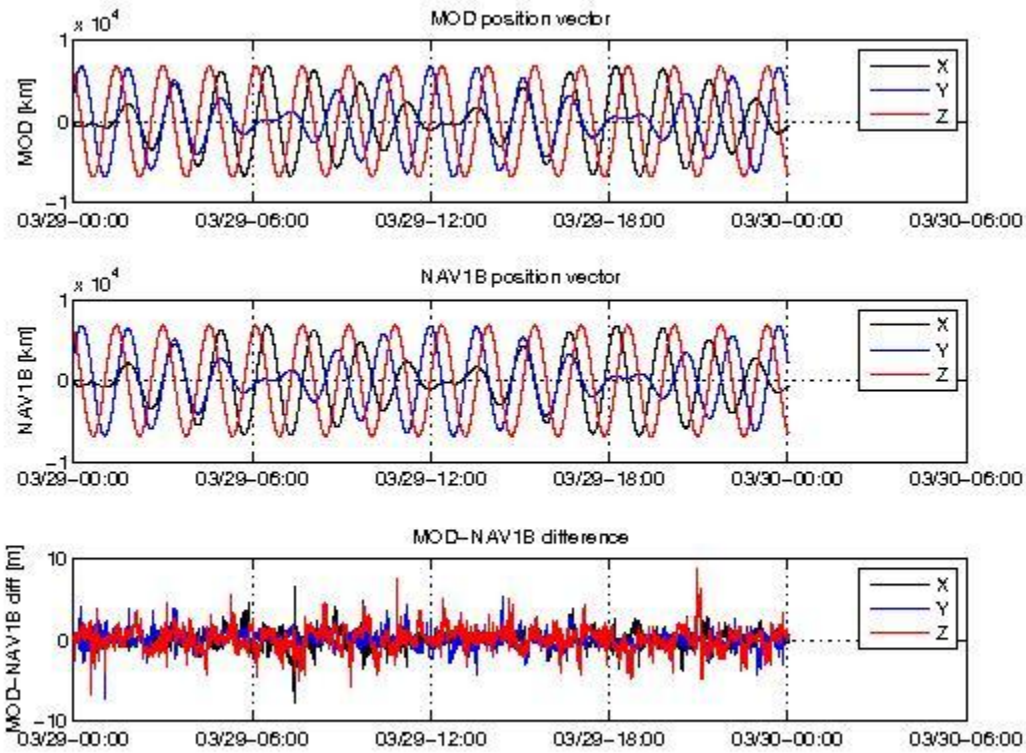

Figure 3: Difference MOD-GPSNAV, S/C A, 29/03. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two. The red circled area shows a big spike in the Y and Z components.

3.2.1.2 Attitude observations

During week 13 an event of out-of-range attitude for S/C A shall be reported. This has been caused by simultaneously not fulfilled conditions of acceptability on all three camera head units. The conditions are the following: BBO, Att_i.Info.Valid, Att_i.Info.Sequence and HighRate (for more details see [RD.14] page 79). This is the reason for rejected attitudes. In Table below, the list of such events for S/C A is given. This is tracked as **SW-IDEAS-66.**

Start time	Stop time	Length (s)
27/03/2015 10:30:48	27/03/2015 10:30:53	6

Table 3 with rejected attitudes due to SW-IDEAS-63

3.2.2 Swarm B

3.2.2.1 Position Statistics

In Table 4 one can see the statistics of the differences between MOD and on-board solution positions. 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 B, 23/03 - 29/03, Position difference					
Day	**Average Difference (m)**	**Maximum difference (m)**		**Standard Deviation (m)**	**Notes**
23/03	0.10	-14.4	21.5 (Y)	1.43	
24/03	0.11	-9.7	7.6	1.29	
25/03	0.06	-6.5	8.9	1.55	SW-IDEAS-34 [RD.10]
26/03	0.12	-7.5	7.0	1.37	
27/03	0.14	-8.4	6.9	1.37	
28/03	0.12	-18.3 (X)	19.3 (X)	1.41	
29/03	0.14	**-94.0**	**77.1 (X)**	1.71	SW-IDEAS-61 (big spikes)

Table 4: Swarm B, difference between MOD and on-board solution positions. If not specified maximum difference and maximum standard deviation refers to the Z axis.

Below some plot example follows of such differences taken at the beginning of the week (23/03, Figure 4), in the middle (26/03, Figure 5), and at end of the week (29/03, 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].

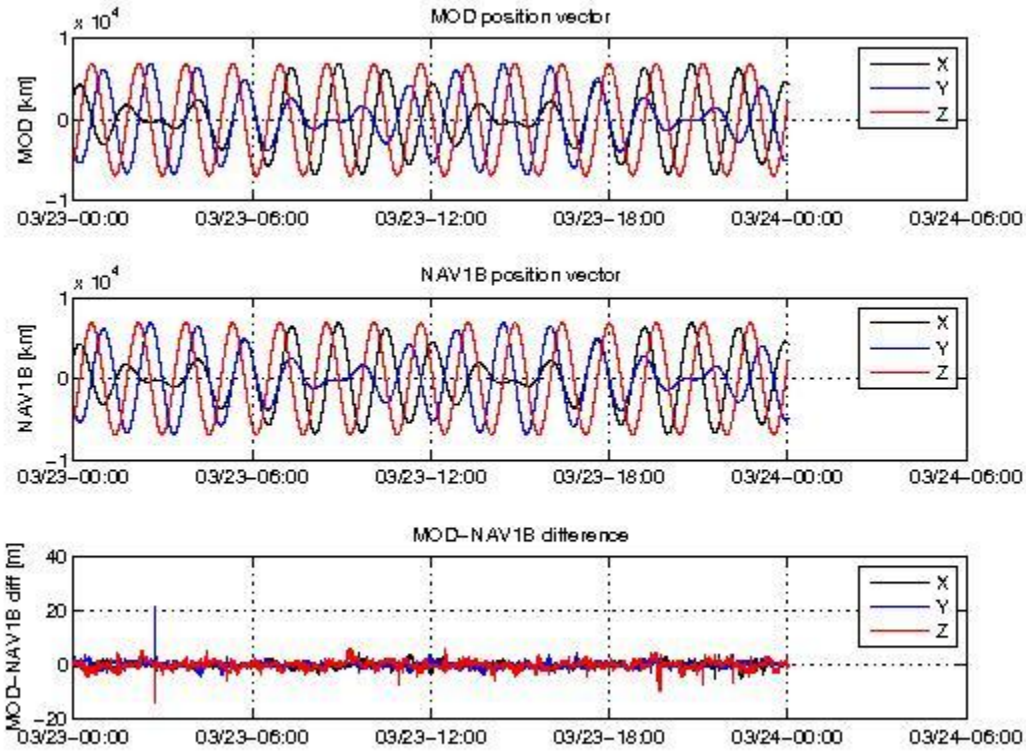

Figure 4: Difference MOD-GPSNAV, S/C B, 23/03. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

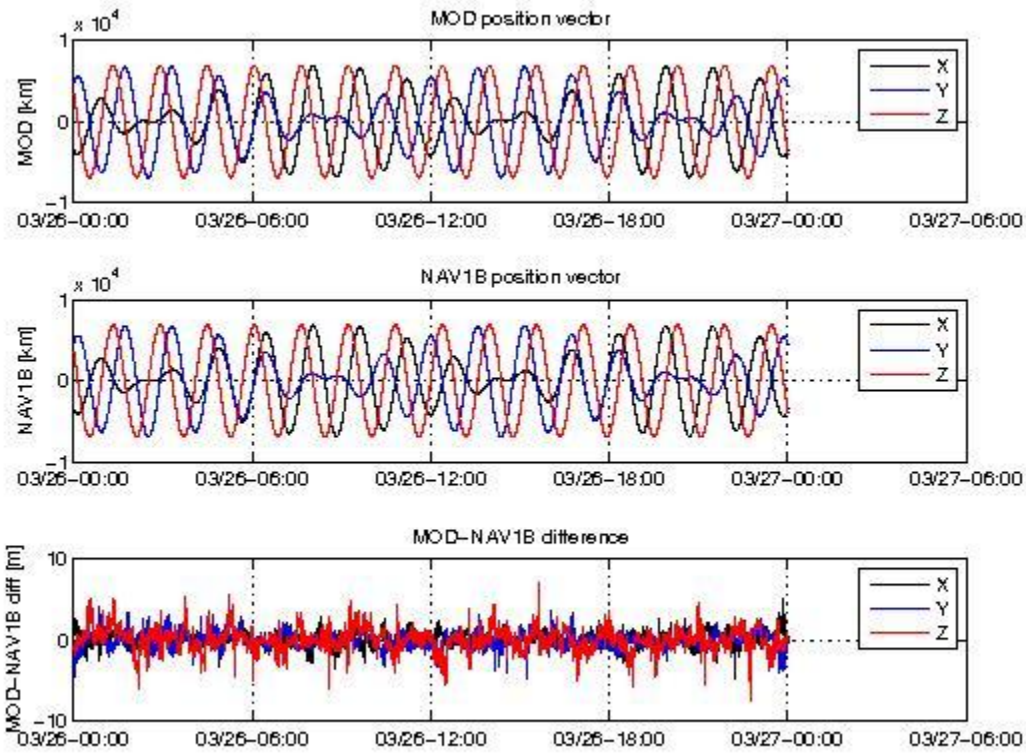

Figure 5: Difference MOD-GPSNAV, S/C B, 26/03. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

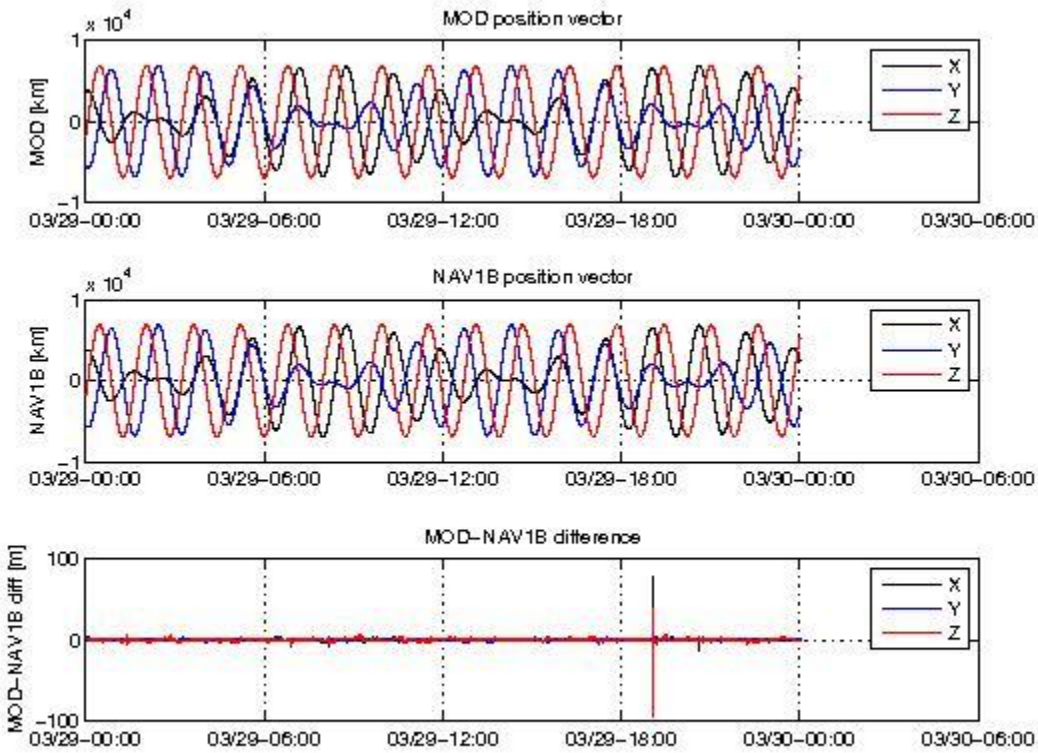

Figure 6: Difference MOD-GPSNAV, S/C B, 29/03. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two. Around 19 UT one can see a big spike in the X and Z components.

3.2.2.2 Attitude observations

During week 13 one of two GPS Sync losses which were detected caused rejection of attitude observations. As explained in [RD.12], this affects the STR data, causing rejection of packets in the Level 1A products and filling gaps with zero quaternions and Flags_q = 255 in the Level 1B products. In Table below, the list of such events for S/C B is given.
There was also one GPS Synch Loss event at 20.54.37 UTC on 2015/03/28, which did not affected attitude.

Start time	Stop time	Length (s)
25/03/2015 21:52:56	25/03/2015 21:53:07	13

Table 5 Attitudes out-of-range, S/C B, week 13.

3.2.3 Swarm C

3.2.3.1 Position Statistics

In Table 6 one can see the statistics of the differences between MOD and on-board solution positions. 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 C, 23/03 - 29/03, Position difference					
Day	**Average Difference (m)**	**Maximum difference (m)**		**Standard Deviation (m)**	**Notes**
23/03	0.09	-6.3	7.3 (Y)	1.29	
24/03	0.16	-8.7	9.8 (X)	1.29	
25/03	0.14	-8.6	10.3	1.63	
26/03	0.17	-6.4 (Y)	6.9	1.31	
27/03	0.07	-9.2	5.5	1.33	
28/03	0.11	-9.4 (X)	8.1	1.34	
29/03	0.16	-6.9 (Y)	7.3	1.23	

Table 6: Swarm C, difference between MOD and on-board solution positions. If not specified maximum difference and maximum standard deviation refers to the Z axis.

Below some plot example of such differences follows, taken at the beginning of the week (23/03, Figure 7), in the middle (26/03, Figure 8) and at the end (29/03, 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]

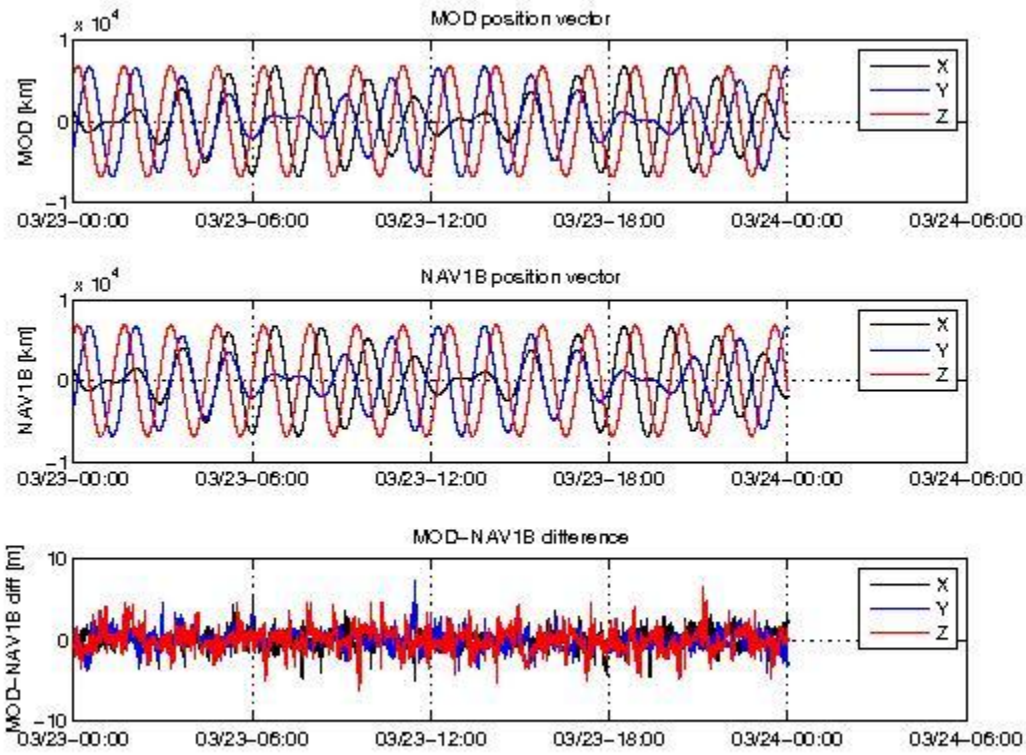

Figure 7: Difference MOD-GPSNAV, S/C C, 23/03. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

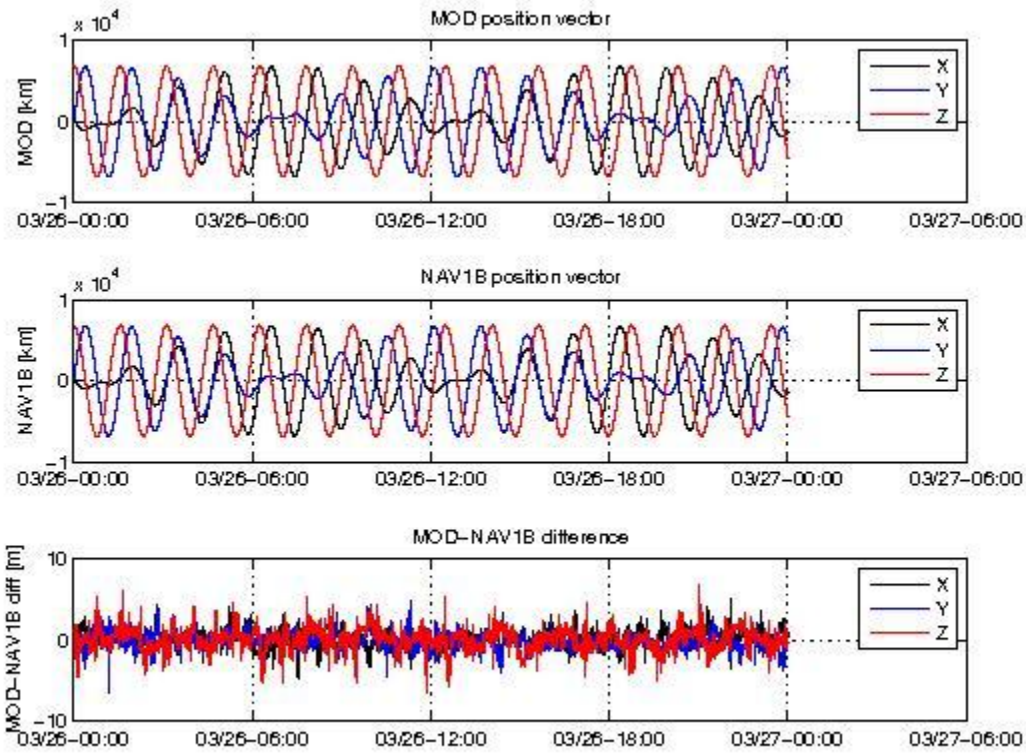

Figure 8: Difference MOD-GPSNAV, S/C C, 26/03. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

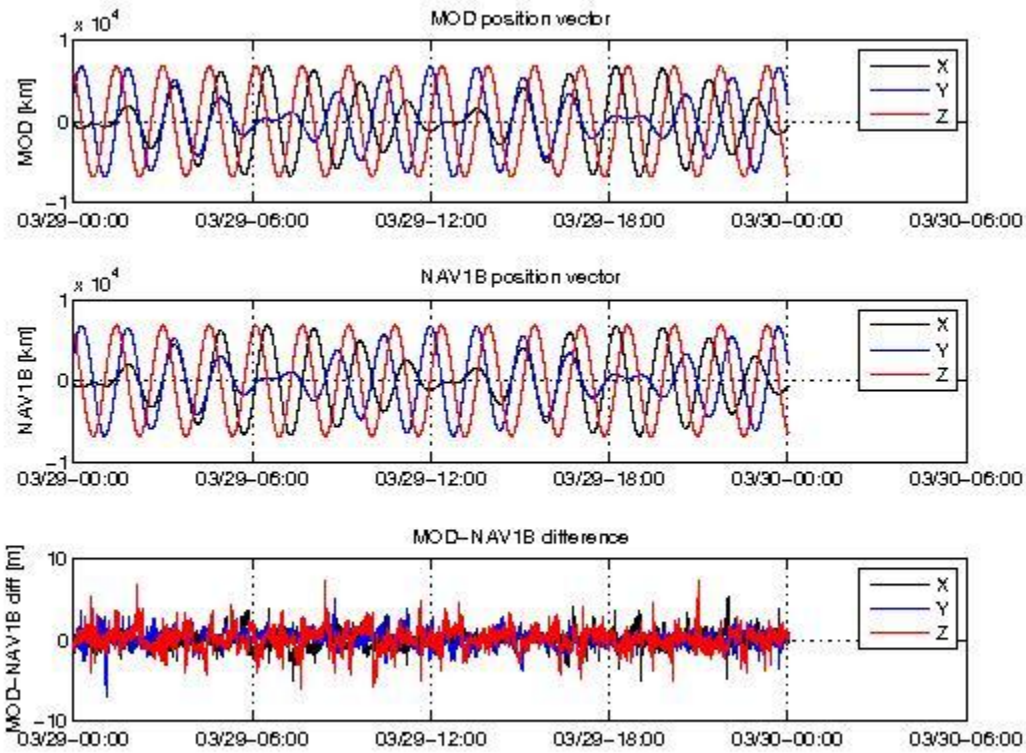

Figure 9: Difference MOD-GPSNAV, S/C C, 29/03. From top to bottom: the S/C position determined from the MOD calculation, the S/C position determined on-board, and the difference between the two.

3.2.3.2 Attitude observations

Nothing to report.

3.3 Magnetic Products

For the magnetic products the weekly monitoring consists in:

- 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.**

3.3.1 Swarm A

3.3.1.1 Magnetic time series visual inspection

An example of representative magnetic field time series for S/C B (29/03) can be seen in Figure 10 below.

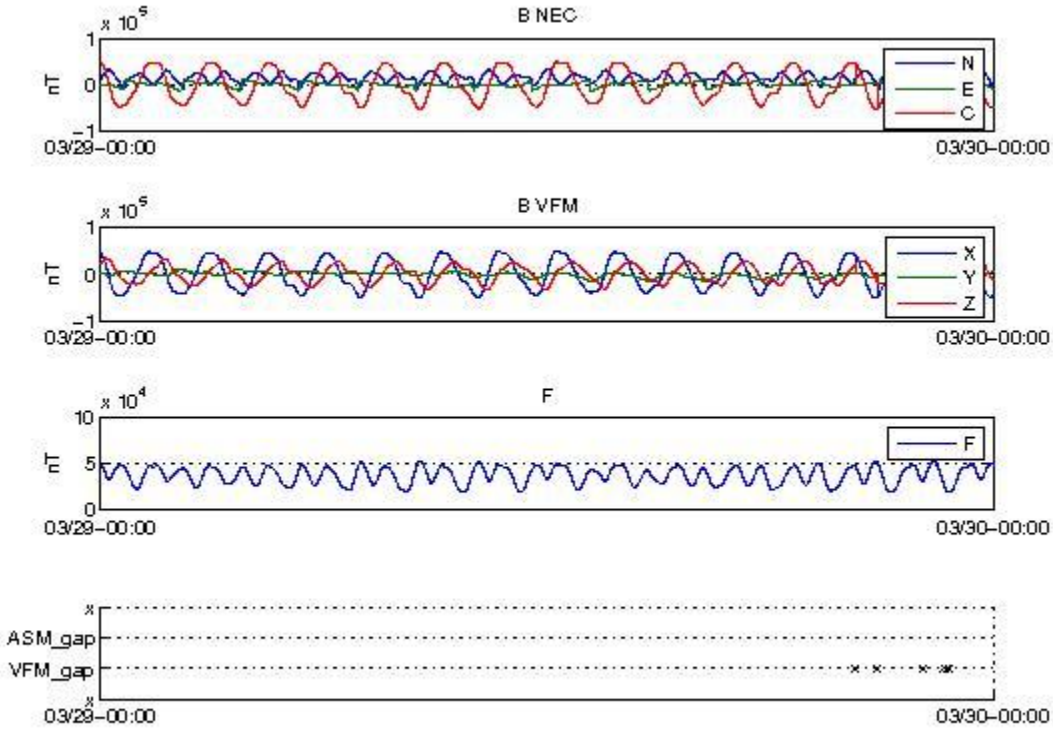

Figure 10: Time series of the geomagnetic field, for 29/03, S/C A. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM, and location of gaps.

3.3.1.2 VFM-ASM anomaly

The daily peak-to-peak difference for the only available day during current week stays within [-2, +2] nT with one spike exceeding 10nT.

Below two example plots follows of such differences: 23/03 (Figure 11), and 29/03 (Figure 12). From top to bottom the plots show: The VFM module, the ASM module, the difference ASM-VFM

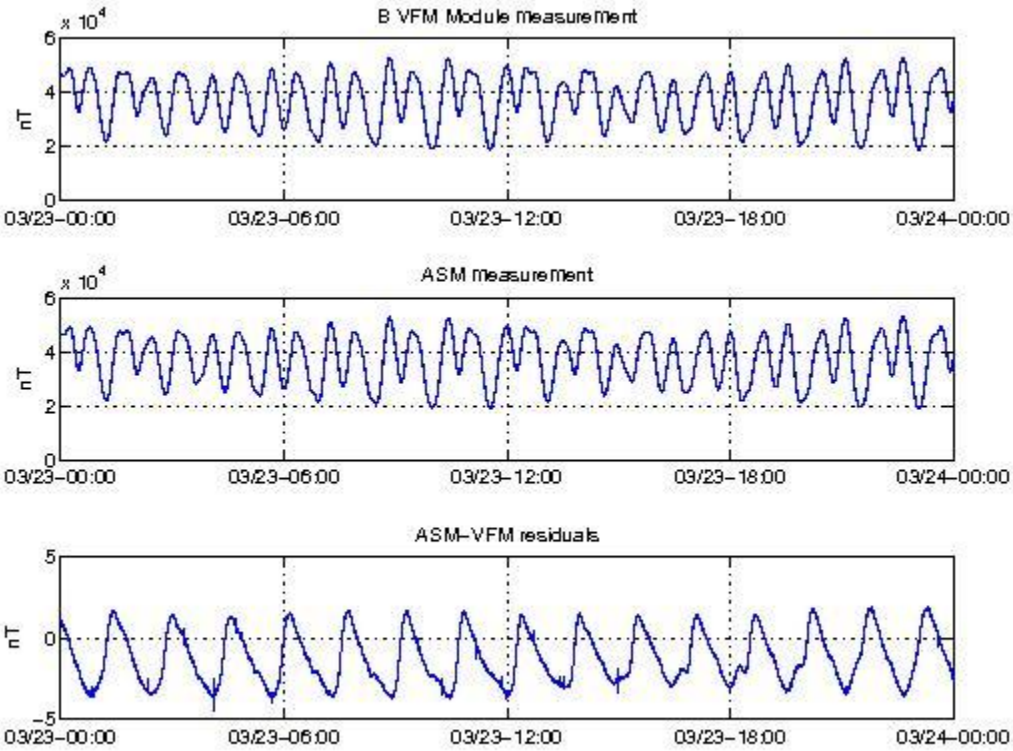

Figure 11: VFM module, ASM module and ASM-VFM residuals for S/C A, 23/03.

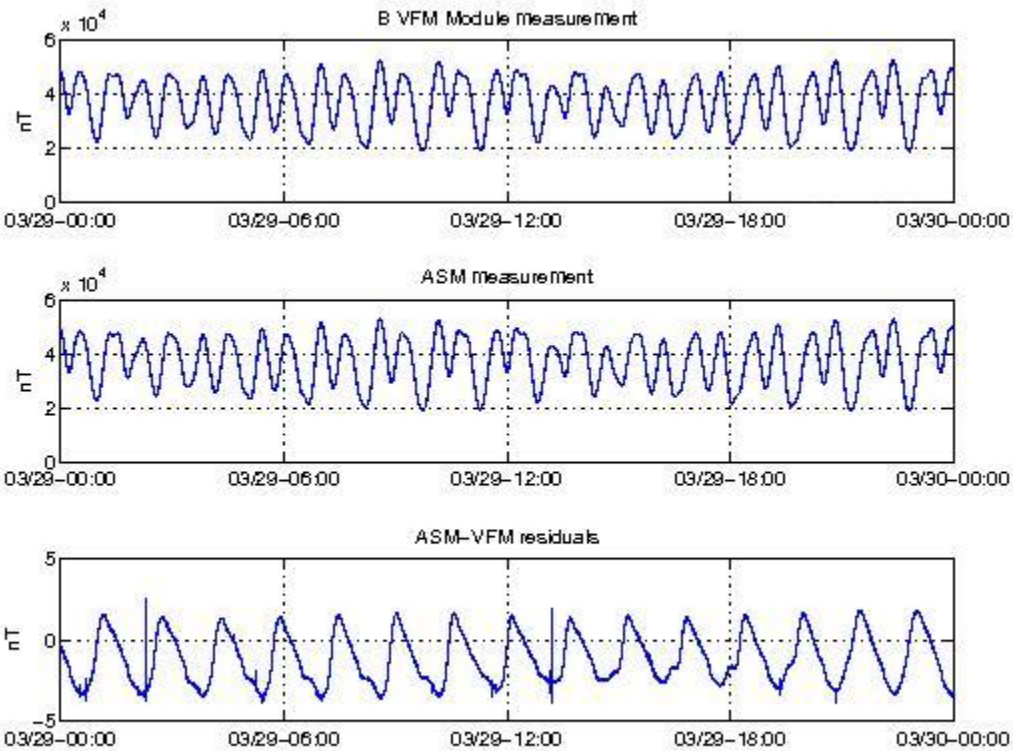

Figure 12: VFM module, ASM module and ASM-VFM residuals for S/C A, 29/03.

3.3.1.3 TCF.VFM monitoring

The TCF.VFM monitoring is a monthly check and will be contained in the first report of April, related to March 2015.

3.3.2 Swarm B

3.3.2.1 Magnetic time series visual inspection

An example of representative magnetic field time series for S/C B (29/03) can be seen in Figure 13 below.

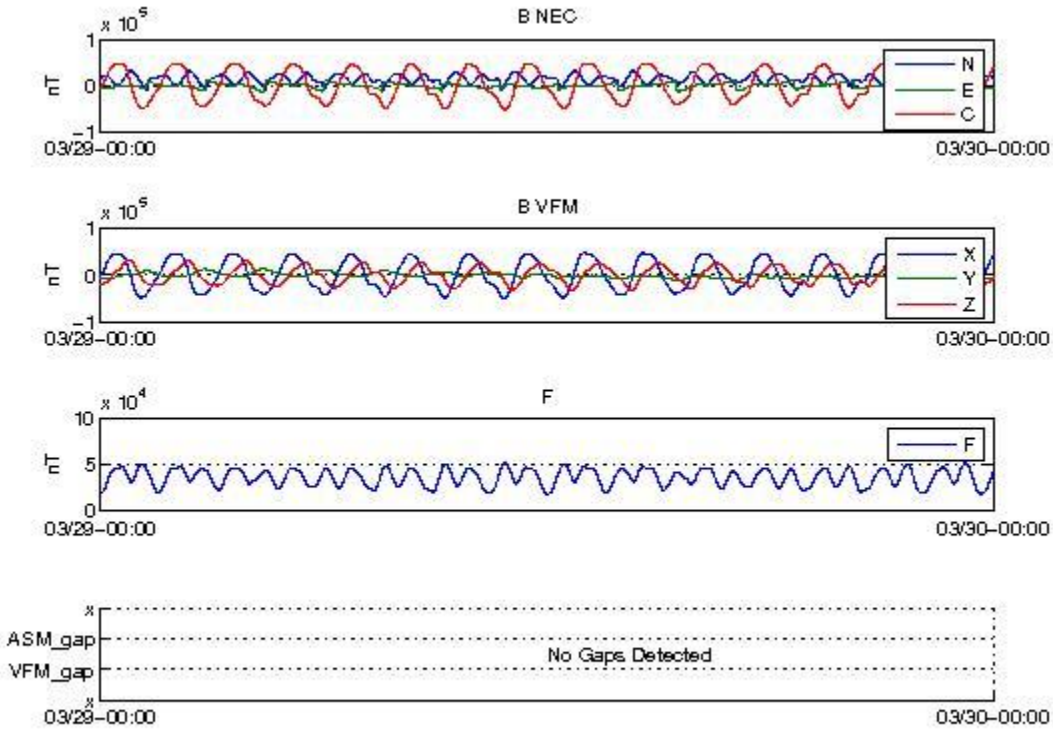

Figure 13: Time series of the geomagnetic field for 29/03, S/C B. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM, and location of gaps (if any).

3.3.2.2 VFM-ASM anomaly

The daily peak-to-peak difference around the week is, on average: [-2.5, 1.5] nT, with a few peaks of about 5 nT.

Below two example plots follows of such differences: 23/03 (Figure 14), and 29/03 (Figure 15). From top to bottom the plots show: The VFM module, the ASM module, the difference ASM-VFM.

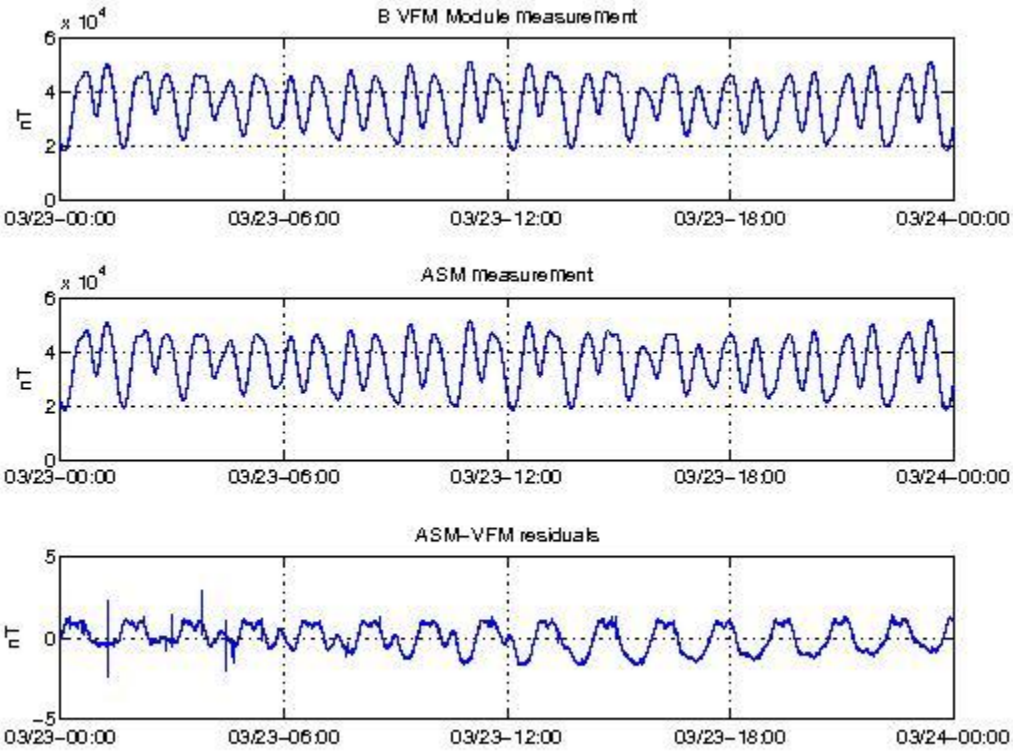

Figure 14: VFM module, ASM module and ASM-VFM residuals for S/C B, 23/03.

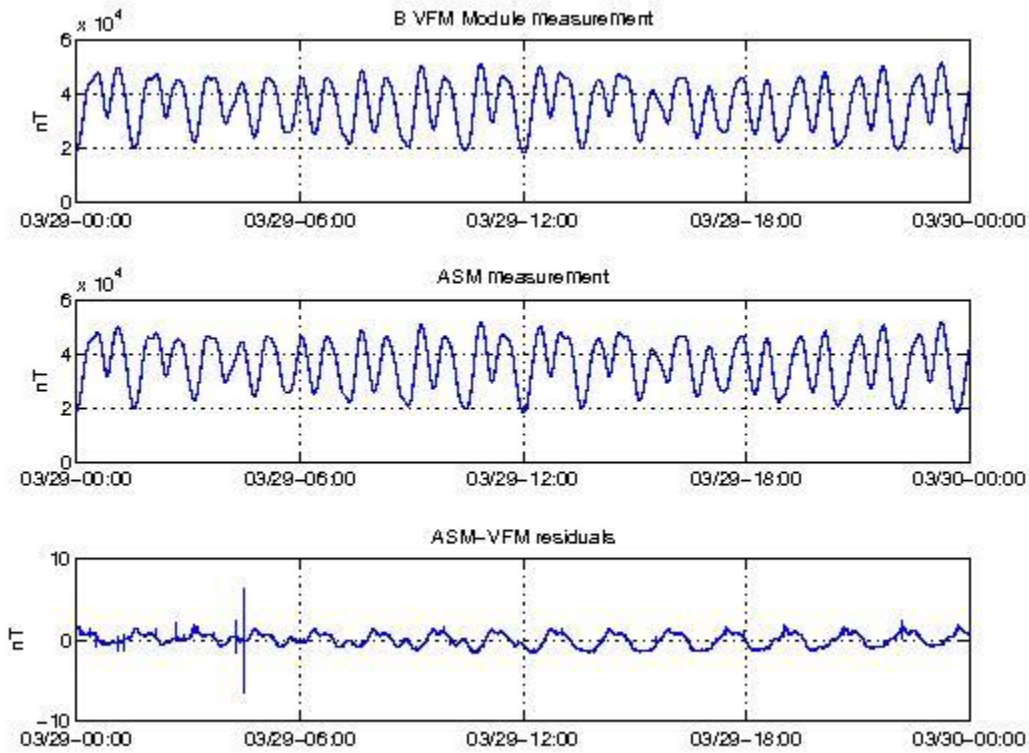

Figure 15: VFM module, ASM module and ASM-VFM residuals for S/C B, 29/03.

3.3.2.3 TCF.VFM monitoring

The TCF.VFM monitoring is a monthly check and will be contained in the first report of April, related to March 2015.

3.3.3 Swarm C

3.3.3.1 Magnetic time series visual inspection

An example of magnetic field time series for S/C C (29/03) can be seen in Figure 16.

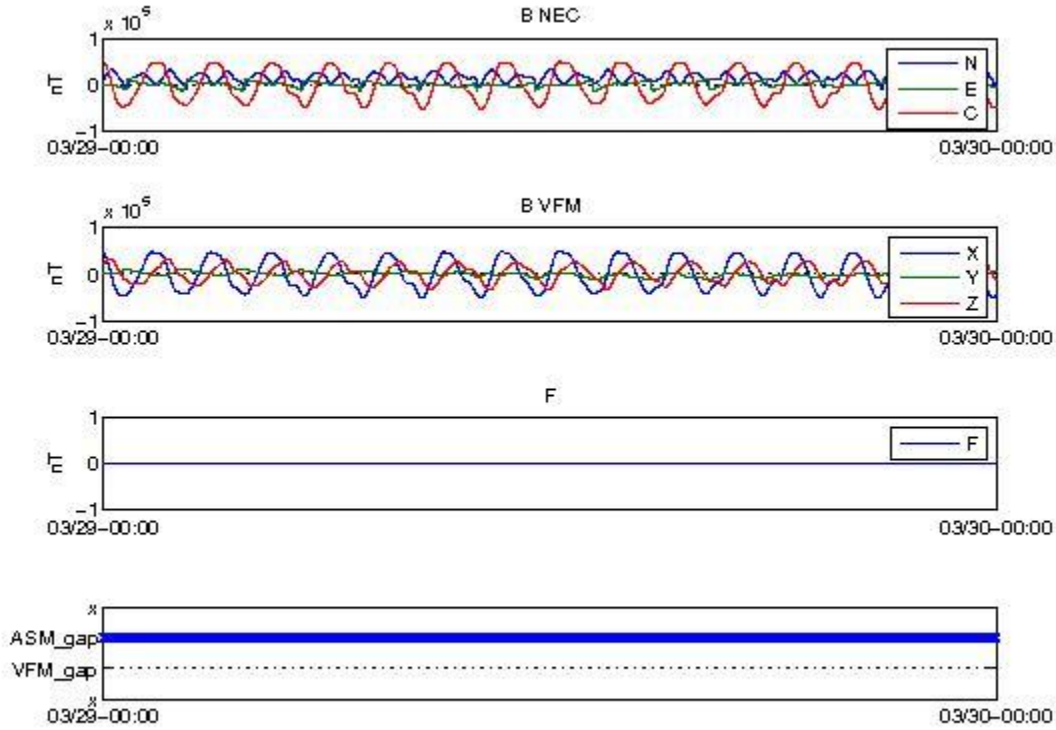

Figure 16: Time series of the geomagnetic field for 29/03, S/C C. From top to bottom: magnetic field components in NEC reference frame, magnetic field components in the VFM reference frame, magnetic field intensity (F) from ASM (no data here because ASM it is off) and location of gaps.

3.3.3.2 VFM-ASM anomaly

No data because ASM is switched off.

3.3.3.3 TCF.VFM monitoring

No data because ASM is still switched off

3.3.4 Summary of TCF behaviour for the three S/C

The TCF.VFM monitoring is a monthly check and will be contained in the first report of April, related to March 2015.

4. ON-DEMAND ANALYSIS

4.1 Cross correlation of GPS out of Sync with MOD-NAV spikes

This section aims at showing a preliminary analysis of correlation between Swarm GPS out-of-sync events and MOD-NAV spikes observed between 9 and 28 March 2015. A more comprehensive analysis will follow in the coming weeks.

Table 7 below shows GPS out of sync. (OOS) occurrences together with MOD-NAV spikes greater than 18 meters for S/C A and C. Events when a MOD-NAV spike occurred shortly after GPS OOS has finished are highlighted in green. Usually the time delay between the two was not greater than 6 seconds. In two cases a spike occurred before GPS OOS (highlighted in orange in Table 7): time delay for those two cases was not longer than 10 seconds.

However, in most cases, MOD-NAV spikes and OOS events are not correlated. This is always the case for S/C B, as shown in Table 8.

S/C A	
MOD-NAV > 18 A	GPS out of sync A
11/03 22:11:48 11/03 22:13:52	
11/03 22:14:43 11/03 22:14:57	11/03 22:13:54 11/03 22:14:38
12/03 04:22:58 12/03 04:25:09	
	12/03 21:40:05 12/03 21:40:08
13/03 19:33:43 13/03 19:34:23	13/03 19:33:24 13/03 19:33:37
	14/03 03:16:29 14/03 03:16:37
14/03 22:04:44 14/03 22:07:01	14/03 22:07:12 14/03 22:07:37
	17/03 00:02:01 17/03 00:02:07
17/03 09:20:40 17/03 09:21:44	
17/03 14:03:43 17/03 14:04:54	17/03 14:02:17 17/03 14:03:38
	20/03 01:21:31 20/03 01:21:37
	20/03 23:19:55 20/03 23:20:00

S/C C	
MOD-NAV > 18 C	GPS out of sync C
	09/03 23:20:40 09/03 23:21:07
	10/03 17:58:50 10/03 17:59:08
	10/03 21:13:32 10/03 21:14:09
	10/03 22:39:19 10/03 22:39:38
11/03 01:48:47 11/03 01:49:24	
	11/03 15:57:49 11/03 15:58:08
11/03 22:13:38 11/03 22:14:12	
	12/03 21:39:43 12/03 21:40:08
14/03 03:17:43 14/03 03:17:58	14/03 03:16:58 14/03 03:17:38
	14/03 18:52:40 14/03 18:53:07
15/03 02:36:43 15/03 02:37:00	15/03 02:36:08 15/03 02:36:38
15/03 02:41:23 15/03 02:43:15	15/03 02:43:17 15/03 02:44:12
	15/03 21:33:24 15/03 21:33:38
17/03 09:28:41 17/03 09:29:18	
17/03 14:04:13 17/03 14:04:52	17/03 14:01:50 17/03 14:04:08
20/03 23:21:13 20/03 23:22:09	20/03 23:20:55 20/03 23:21:07

Table 7 In each cell, beginning and end times of a GPS out of Sync (right columns) and MOD-NAV spikes (left columns) are reported, for S/C A (table on the left) and S/C C (table on the right). With green/orange background spikes occurring just after/before GPS out of sync respectively are evidenced.

S/C B	
MOD-NAV > 18 B	GPS out of sync B
	17/03 18:53:17 17/03 18:54:08
23/03 02:43:15 23/03 02:45:22	
28/03 20:52:21 28/03 20:54:35	
28/03 20:54:43 28/03 20:55:47	

Table 8: In each cell, beginning and end times of a GPS out of Sync (right columns) and MOD-NAV spikes (left columns) are reported, for S/C B.

4.2 ASM VFM additional analysis

In Figure 17 one can see the daily absolute maxima (crosses) and minima (squares) of the ASM-VFM residuals for S/C A (upper panel) and S/C B (lower panel). It is observed that, for S/C Alpha, the absolute value of minimum of the ASM-VFM difference is almost always greater than the maximum.

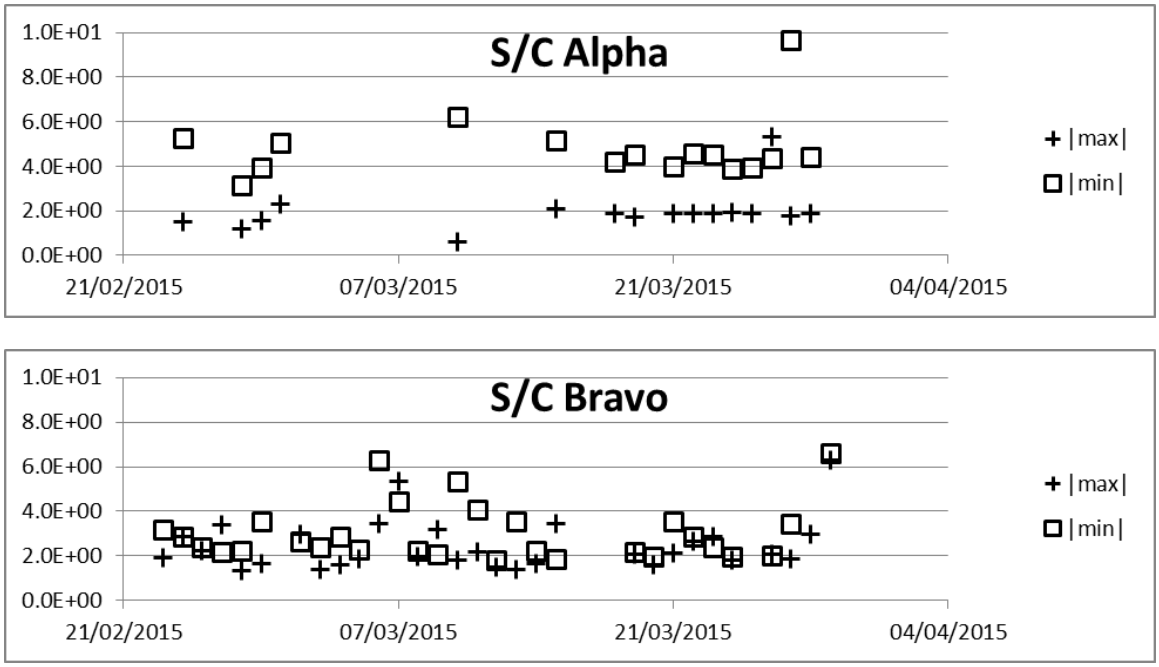

Figure 17: Absolute values of ASM - VMF maxima and minima as a function of time for S/C A (upper panel) and S/C B (lower panel).

In Figure 18 the daily standard deviation (STD) of the ASM-VFM residuals is shown for S/C A (diamonds) and S/C B (crosses). It is observed that STD has increased for S/C Alpha starting from 7th of March. For S/C Bravo it remains at a constant level.

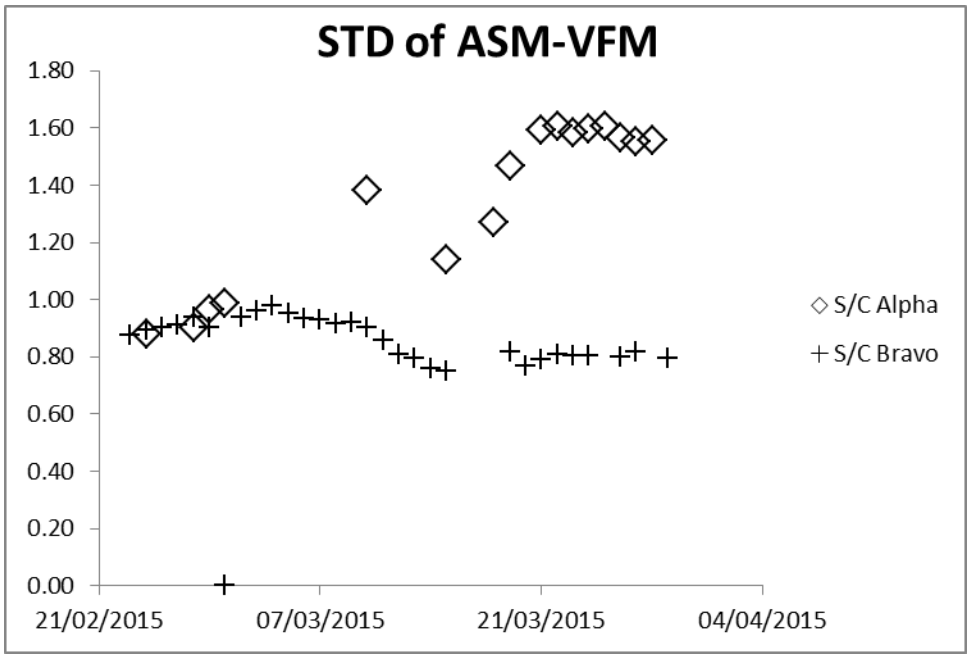

Figure 18: Standard deviation of the ASM-VFM residuals of the last month, for S/C A and B.

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