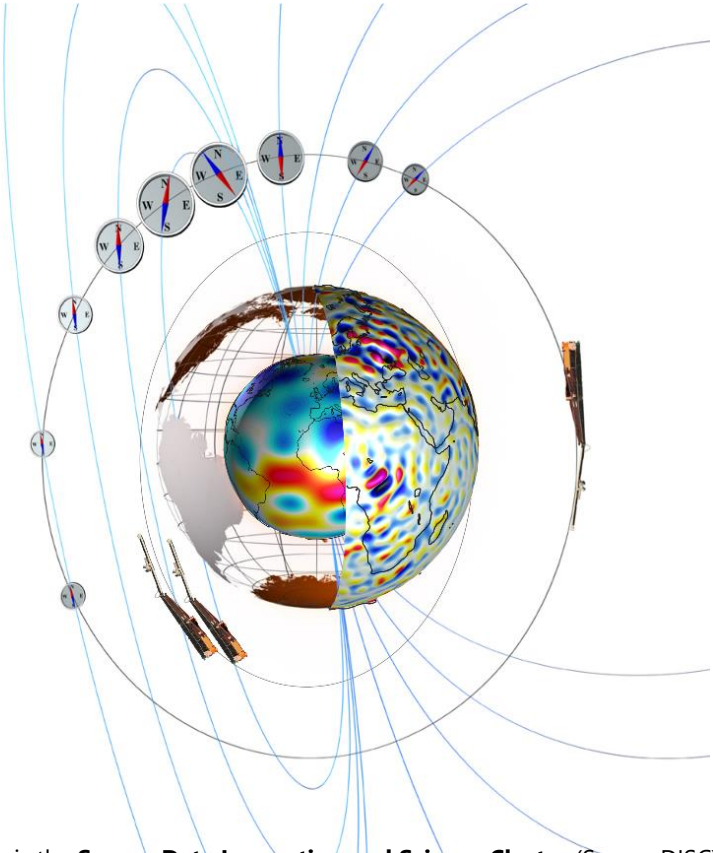
Swarm DISC Weekly Report 2019/16: 2019/04/15 - 2019/04/21



Abstract : This is the **Swarm Data Innovation and Science Cluster** (Swarm DISC) Weekly report on Swarm products quality, covering the period from 15 April 2019 to 21 April 2019.

Doc. No : SW-RP-SER-GS-010

Author : Martyna Romanowska and Filomena Catapano on behalf of Swarm DISC Team

Approval : Jerome Bouffard
ESA – EOP/GMQ

Distribution : ESA/ESRIN EOP-GMQ
ESA/ESRIN EOP-GM Swarm MM
Swarm DISC Management Team
Swarm DISC subcontractors
ESA/ESTEC Swarm PLSO
ESA/ESOC Swarm FOS

TABLE OF CONTENTS

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	02 Jul 2019	First issue

1. Introduction

This document refers to the activities carried out in the framework of the ESA Sensor Performance, Products and Algorithms (SPPA) Office [RD.1].

Chapter 1 gives an overview on the outcomes from the annual Swarm Data Quality Workshop and reports the information on the current operational configuration and its future improvements. It also contains the list of used reference documents.

In Chapter 0, the Section 2.1 gives an overview of the general quality status of the Swarm mission instruments and products, while the main observations of the week are summarized in the 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. If interested in accessing the reports via web or FTP, please contact the Swarm DISC team at the following email address: <swarm@eo-sppa.org>. Such data quality reports represent the main component of the Routine Quality Control performed by ESA SPPA (Chapter 3). A description of the implemented quality checks is given in [RD.2], and references therein.

Based on specific findings of the routine quality control, or requests from other entities (i.e. Swarm Payload Data Ground Segment (PDGS), Flight Operation Segment (FOS), Mission Management, Post-Launch Support Office (PLSO), Expert Support Laboratories (ESL), Quality Working Groups (QWG), and user community), investigations on anomalies can be triggered. Preliminary characterisations of possibly detected anomalies are given in Chapter 4 .

Information on Swarm Level 1B products can be found in [RD.3].

This weekly report is based on QC methods and diagnostics that tend to be continuously evolved and improved throughout the mission lifetime, reporting on the data quality, product evolutions, and status of the instruments on weekly basis.

1.1 Annual Swarm Data Quality Workshop

The Swarm Data Quality Workshop takes place each year. The 8th Swarm Data Quality Workshop (DQW#8) held in ESA ESRIN from 08 to 12 October 2018.
The main objectives of the workshop were to:

- Provide an overview of Swarm Mission status to the user Community
- Update the data quality status from Magnetic, Electric, GPSR and accelerometer measurements
- Discuss new Swarm-based Scientific results

Besides the usual Cal/Val topics, this Swarm DQW#8 has also allowed to address new technical, scientific and strategic challenges related to:

- Swarm-based Multi-disciplinary applications
- Swarm-based Data processing virtual environments
- Swarm-based Machine Learning methods
- Multi-mission synergies (e.g. with CryoSat, Goce, e-POP, CSES etc.)

The Swarm DQW#8 was an occasion to discuss potential synergetic benefits obtained through collaboration initiatives with ESA's partner agencies and other sensor systems.
A complete summary of the recommendations based on the contributions from Swarm DQW#8 sessions can be found at [RD.4] and [RD.5].

1.2 Current Operational configuration of monitored data:

Processors	
Name	**Version**
L1BOP	v3.20p1
L2-Cat2	v01.18p2
Products	
Name	**Baseline**
L0 inputs	02
L1B MAGNET and PLASMA	05
L1B ORBATT and ACCELE	04
L2-Cat2 EEF*	01
L2-Cat2 IBI, FAC and TEC	03
Others	
Input auxiliary files	S/C A, CCDB 0022 (06/03/2019) S/C B, CCDB 0022 (02/01/2019) S/C C, CCDB 0023 (06/03/2019)
MPPF-CVQ	v03.07 (27/12/2018)

1.3 Recent evolutions

The L1BOP v03.21 has been delivered on 11/03/2019, and the L2 Cat-2 OP v01.19 has been delivered on 13/03/2019. These new versions of the operational processors contain only the porting to a newer operational system, Red Hat Enterprise Linux 7.5. No evolutions of the processor algorithms are included in this delivery. The PDGS Team generated the test scenarios in order to compare their outputs with the ones from GMV. Also, a comparison with the L1BOP v03.20 is on-going by the Data Quality Team.

1.4 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 MPPF-CVQ Monitoring Baseline Document, ST-ESA-SWARM-MBD-0001, Issue 1.7.

[RD.3] Swarm Level 1B Product Definition, SW-RS-DSC-SY-0007, Issue 5.23.

[RD.4] https://earth.esa.int/documents/10174/3687590/SWARM-DQW%238-SUMMARY-%26-RECOM-VFINAL.pdf/73683cc8-be21-47f7-a1c3-db4a60a911cb

[RD.5] https://eos.org/meeting-reports/the-swarm-satellite-trio-studies-earth-and-its-environment

[RD.6] 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

* The production of the EEF product is temporarily suspended.

2. Summary of the observations

2.1 Changes in the general status of Swarm instruments and Level 1B products quality

Due the increasing image degradation, the EFI TII science orbits for Swarm Charlie have been reduced from 2 to 1 orbit per day starting from 17/04/2019.

2.2 Relevant observations of the week

During the monitored week no particular events have been found or investigated.

3. Routine Quality control

3.1 Gaps analysis

Nominal. Nothing to report.

3.2 Orbit and Attitude Products

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 within the week. We evaluate an anomaly raise if one (or more) of the following conditions is registered :
    - 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.

The following monitor activity is also performed and will be reported only in case of anomaly detection:

- 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 Figure 3-1, 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 standard deviation is in the fourth column. Maxima, minima and standard deviations usually refer to the Z component that is often the most disturbed; in case another component is most affected, it will be specified in parentheses. Figure 3-1 shows a cumulative trend of the maximum daily standard deviation for the past 30 days of operations of the MOD-NAV difference, while Figure 3-2 shows the daily maximum difference, in absolute value, of the MOD-NAV difference, always for the past 30 days of operations.

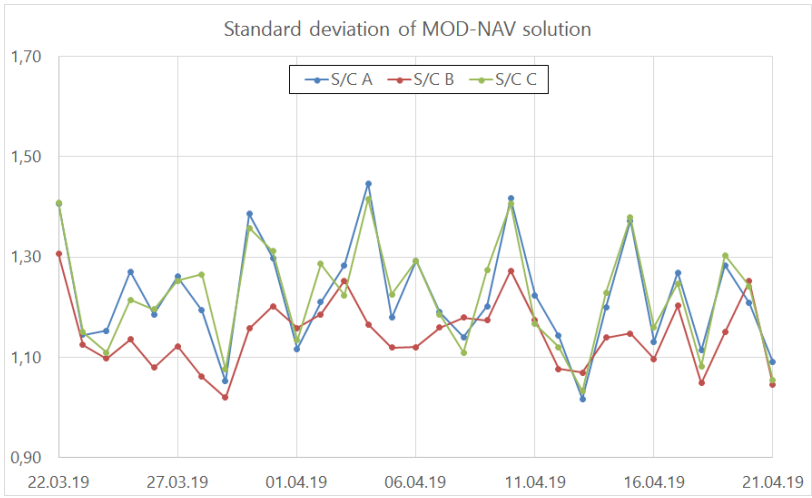


Figure 3-1: Plot of the standard deviation of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.

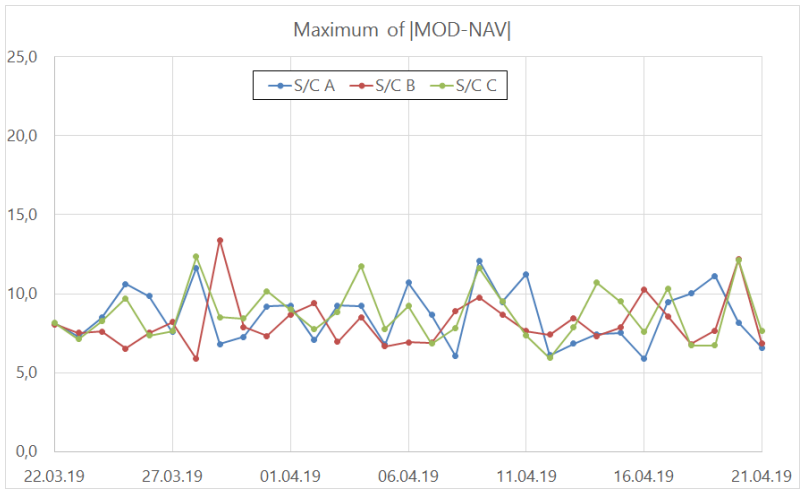


Figure 3-2: Plot of the maximum difference of the absolute value of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.

3.2.2 Attitude observations

3.2.2.1 Swarm A

Nominal. Nothing to report.

3.2.2.2 Swarm B

Nominal. Nothing to report.

3.2.2.3 Swarm C

Nominal. Nothing to report.

3.3 Magnetic Products

For the magnetic products, the weekly monitoring consists of:

- ASM instrument monitoring: quartz frequency (nominal range: [2.949E7 – 2.950E7] Hz) and ASM temperature (temperature range shall be: [-30;+50] °C, Rel. Variation shall not exceed: 0.1 °C/sec).
- VFM instrument monitoring: temperatures (Rel. Variation shall not exceed: 0.1 °C/sec).
- Visual inspection of daily time series of magnetic field intensity F, B_{NEC} and B_{VFM}. Looking for gaps (or zero values in case of MAGx_LR_1B products), out-of-threshold values (i.e. exceeding +/- 60000 nT), and other strange features. Map plots of F and B_{NEC} for the whole week are then displayed.
- Monitoring of the ASM-VFM known anomaly: visual inspection of $|B_{VFM}|$ - F taken from MAGx_CA_1B products and recording of daily maximum variations and standard deviations. If +/- 1 nT are exceed on a given day, an alert is raised. Map plots of the residuals are shown along with weekly time series of the residuals with and without the "dB_Sun" correction: in fact, at least a part of the discrepancies found in the measurements between ASM and VFM are modelled through a stray field (dB_Sun) that is a function of the orientation of the VFM wrt Sun.
- Comparison of magnetic data (B_{NEC}) with a model (Chaos5).

3.3.1 VFM-ASM anomaly

- S/C A – no violation of thresholds.
- S/C B – no violation of thresholds.

3.3.1.1 ASM-VFM difference statistics

The ASM-VFM difference is defined as follow:

$dF = |B_{VFM}| - F_{ASM}$

Figure 3-3 and Figure 3-4 show the daily mean (circles) and standard deviation (crosses) of dF of the last month for Swarm A and Swarm B respectively.

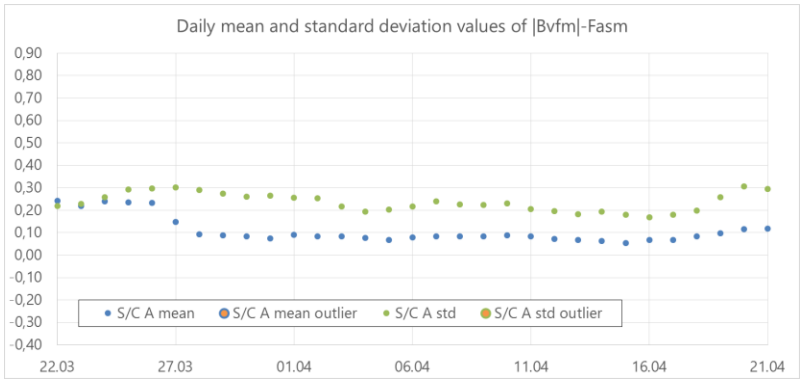


Figure 3-3: Daily mean and standard deviation values of ASM-VFM residuals (defined as $dF=|B_{VFM}|-F_{ASM}$) for S/C A.

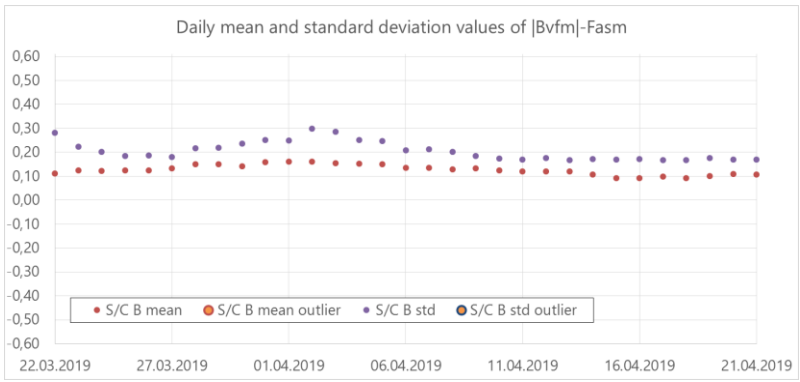


Figure 3-4: Daily mean and standard deviation values of ASM-VFM residuals (defined as $dF=|B_{VFM}|-F_{ASM}$) for S/C B.

3.3.1.2 Swarm A

The daily peak-to-peak difference around the week stays within [-0,49 - 0,81] nT. Below follow two plots of such differences for current week (Figure 3-5).

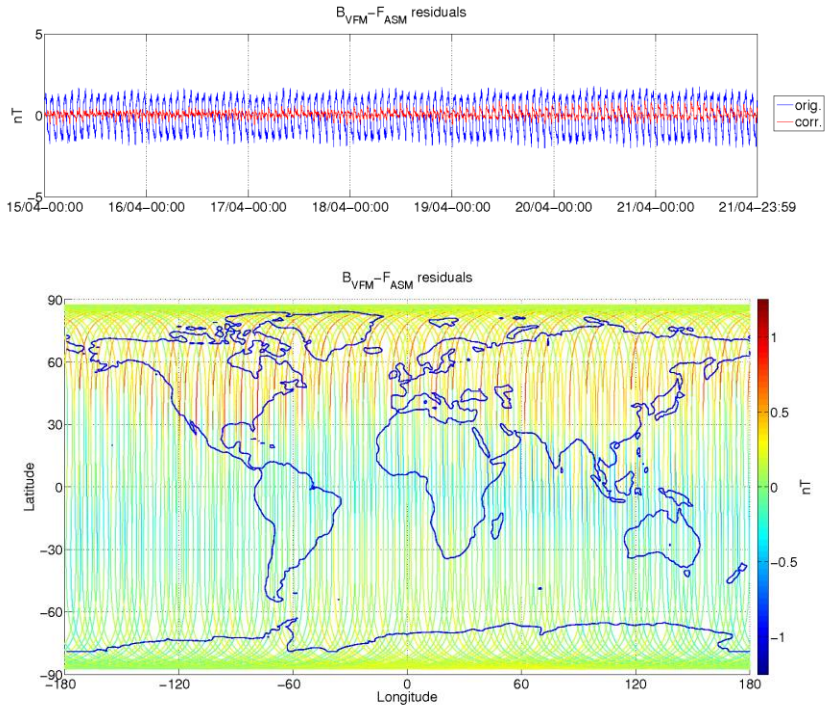


Figure 3-5: ASM-VFM residuals for S/C A, during monitoring period. In top figure are plotted: difference between |B_VFM| and F_ASM (without dB_Sun correction) (blue colour), and the residuals with dB_Sun corrections (red colour). In bottom figure residuals are presented on the world map.

3.3.1.3 Swarm B

The daily peak-to-peak difference around the week stays within [-0,77 - 0,97] nT. Below follow two plots of such differences for current week (Figure 3-6).

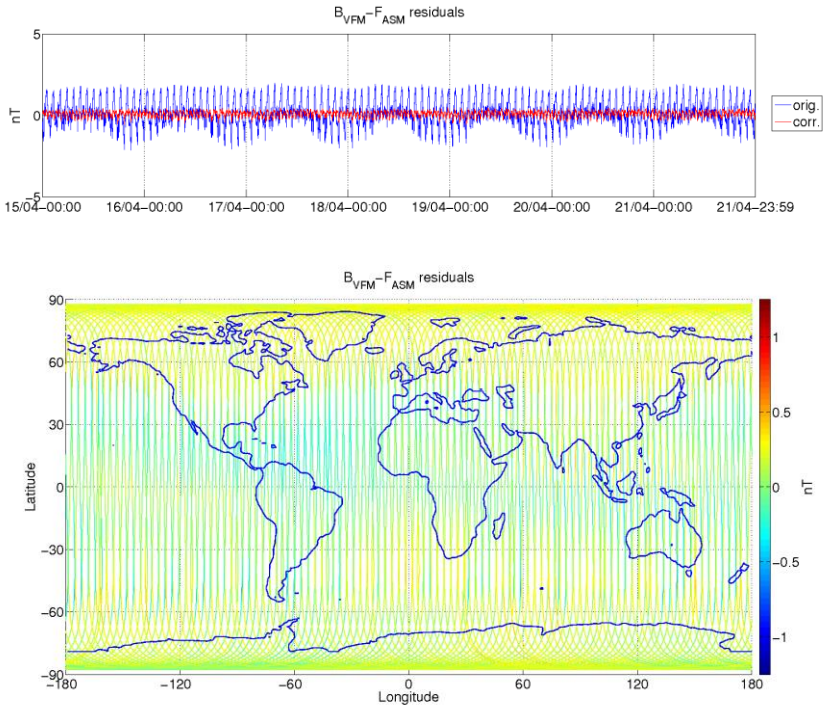


Figure 3-6: ASM-VFM residuals for S/C B, during monitoring period. In top figure are plotted: difference between |B_VFM| and F_ASM (without dB_Sun correction) (blue colour), and the residuals with dB_Sun corrections (red colour). In bottom figure residuals are presented on the world map.

3.3.1.4 Swarm C

No data because ASM is switched off.

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

For S/C A and B, 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 A, B and C, for reported period, the temperatures behaved as expected.

3.3.4 Magnetic time series visual inspection

3.3.4.1 Swarm A

Map plots of magnetic field measurement for week 16 for S/C A can be seen in Figure 3-7 below.

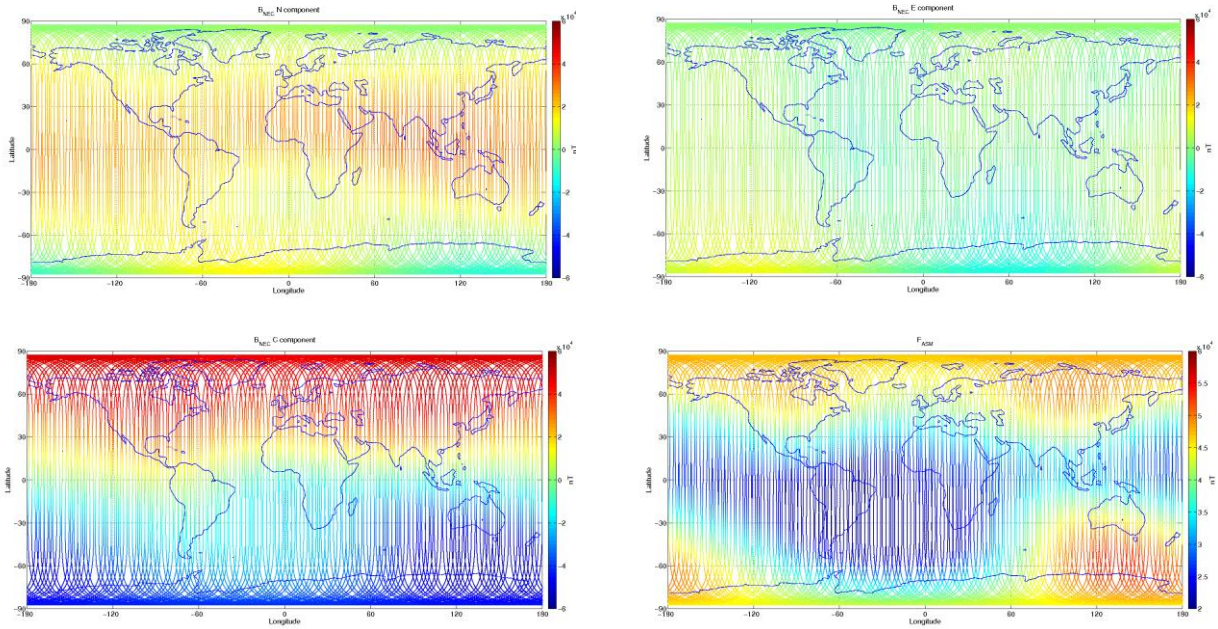
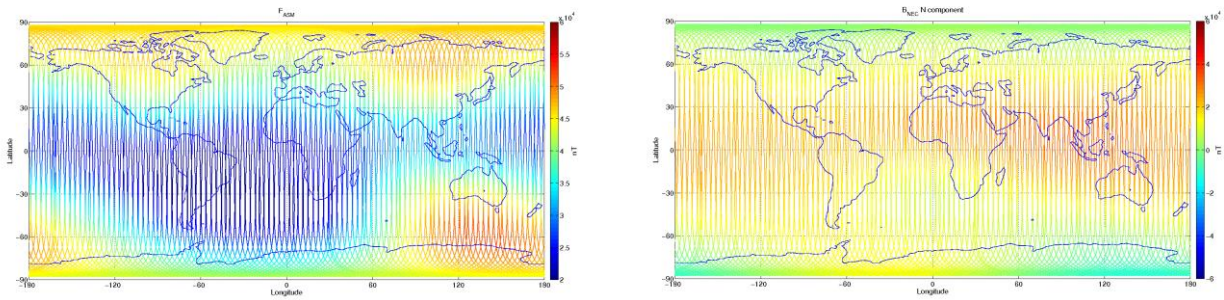


Figure 3-7: S/C A, world map plots of the geomagnetic field and components measured during monitoring period. From top left to bottom right: B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement, F-magnetic field from ASM measurement.

3.3.4.2 Swarm B

Map plots of magnetic field measurement for week 16 for S/C B can be seen in Figure 3-8.



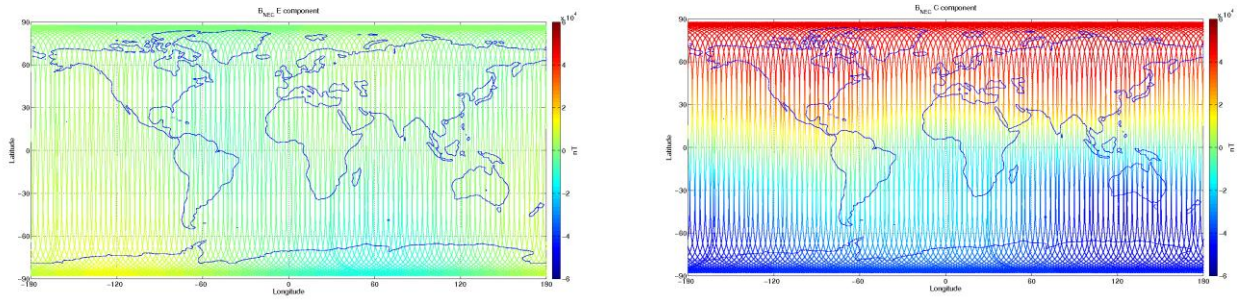


Figure 3-8: S/C B, world map plots of the geomagnetic field and components measured during monitoring period. From top left to bottom right: F-magnetic field from ASM measurement, B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement, F-magnetic field from ASM measurement.

3.3.4.3 Swarm C

Map plots of magnetic field measurement for week 16 for S/C C can be seen in Figure 3-9.

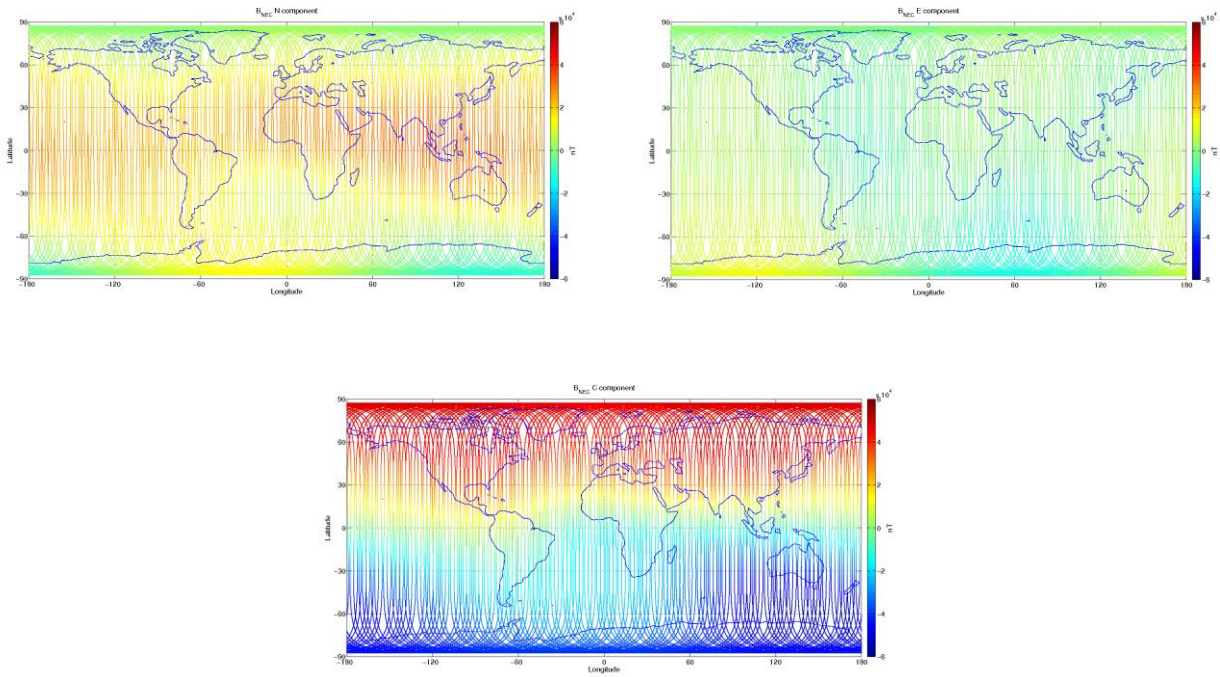


Figure 3-9: S/C C, world map plots of the geomagnetic field and components measured during monitoring period. From top left to bottom right: B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement, F-magnetic field from ASM measurement.

3.3.5 B_{NEC} vs Chaos5 model residuals

The magnetic field measurement is compared to magnetic field estimated from the Chaos5 global geomagnetic field model (only Core and Crustal contributions). Currently in the monitoring routines the external contribution based on Dst index is not taken into account.

Left side of Figure 3-10, Figure 3-11,

Figure 3-12 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.6]).

Right side of Figure 3-10, Figure 3-11,

Figure 3-12 show, from top to bottom, the time series on first day of the week of: (1-2-3) residuals of B_{NEC}-B_{Chaos} by components, related to S/C A, B and C respectively.

The component most affected by residual spikes and variations is $B\theta_{NEC}$, i.e. the component that shows the variations of the field wrt to co-latitude. At high latitudes, the order of magnitude of the variability is about +/- 200 nT.

3.3.5.1 Swarm A

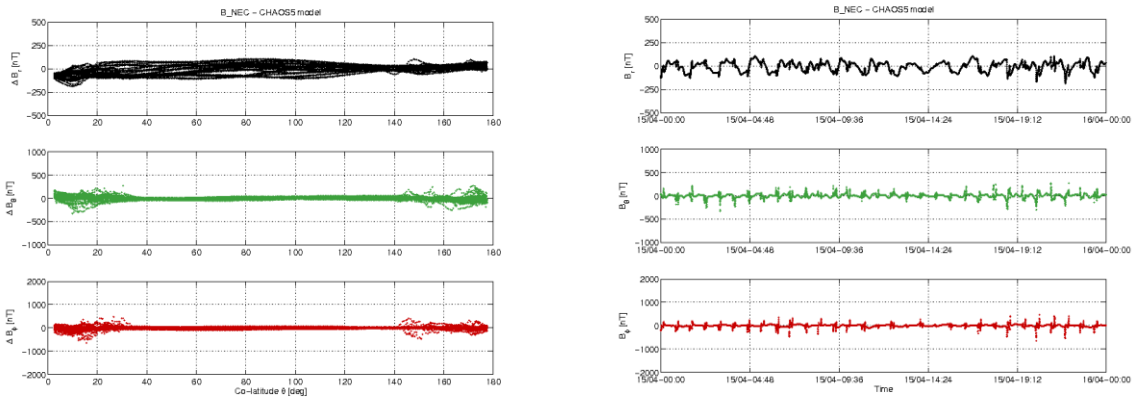


Figure 3-10: S/C A day 15/04: time series of $B_{NEC} – B_{Chaos}$ residuals (right) and B_{NEC} - B_{Chaos} vs colatitude (left).

3.3.5.2 Swarm B

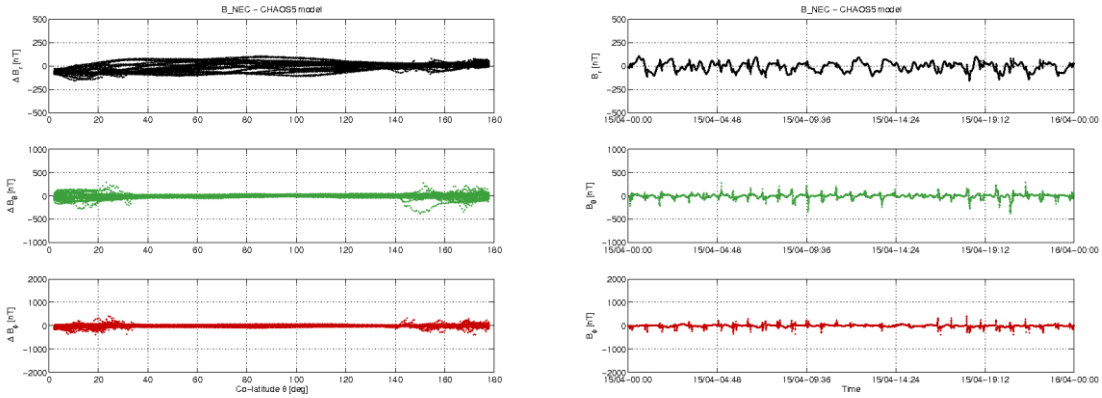


Figure 3-11: S/C B day 15/04: time series of $B_{NEC} – B_{Chaos}$ residuals (right) and B_{NEC} - B_{Chaos} vs colatitude (left).

3.3.5.3 Swarm C

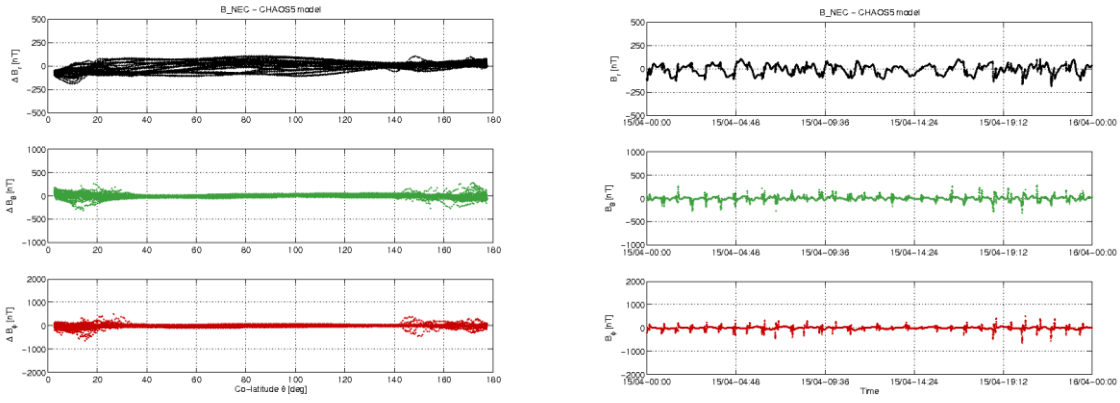


Figure 3-12: S/C B day 15/04: time series of $B_{NEC} – B_{Chaos}$ residuals (right) and B_{NEC} - B_{Chaos} vs colatitude (left).

3.4 Plasma Products

The Monitored plasma products are computed from the EFI-LP instruments and consist in : electron density (Ne) and electron temperature (Te). The monitoring of the data is done on different temporal basis (daily, weekly, monthly, yearly) in order to have a comprehensive knowledge on the data quality. Here we report only two examples of the performed data monitoring, which are the most representative of the data quality.

On Figures from Figure 3-13 to Figure 3-15, are shown the weekly profiles of the electron density and temperature as a function of time for the last week of operations. Data have been down sampled form 1s to 2min in order to have a clearer representation (grey lines). Also, the 20 minutes moving window average is shown in the figures (black points). From these figures, it is possible to see if there are measurements with large discrepancies from the average behaviour, and their time location.

On Figures from Figure 3-16 to Figure 3-18, are shown the variations of the electron density and temperature as a function of the latitudes in quasi-dipole (QD) coordinate system, during the last week of operation. These analysis is useful to study the dependence of the variables on the QD magnetic coordinate system.

These analysis are shown for the ascending (upper panels) and descending (bottom panels) phase orbits, separately.

It is visible that sometimes the electron temperature reaches very high values, exceeding ten thousands of Kelvin, particularly at high latitudes. The nature of this feature is currently under investigation.

3.4.1 Plasma time series visual inspection

3.4.1.1 Swarm A

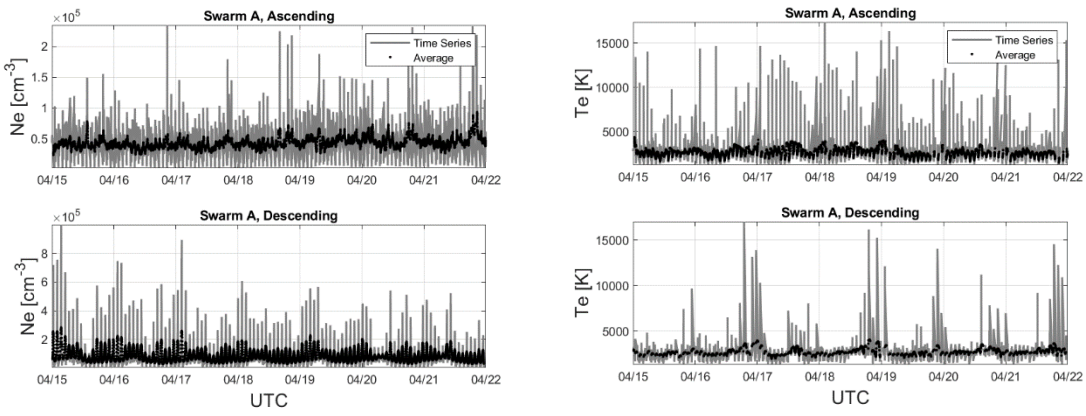


Figure 3-13: The panels show the electron density (left) and temperature (right) weekly time series (grey lines) together with the 20 min moving windows average (black lines). The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits. The average magnetic local time during the week is 5 a.m. for ascending phase and 5 p.m. for descending phase.

3.4.1.2 Swarm B

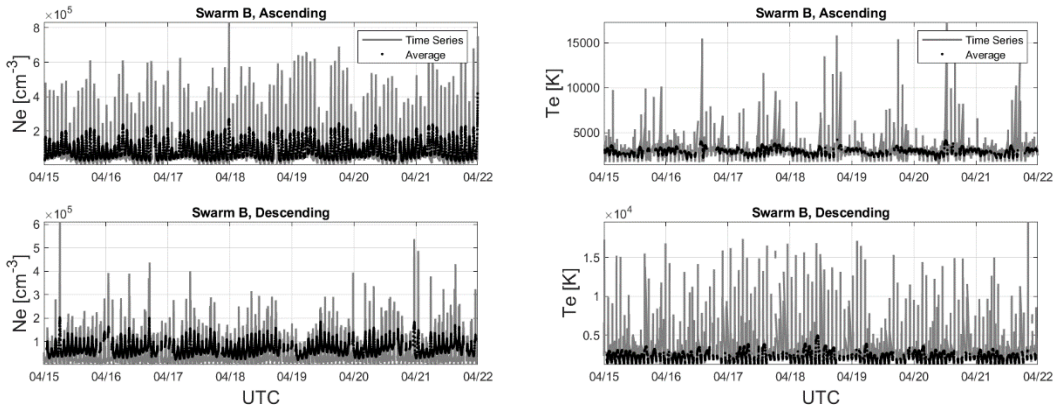


Figure 3-14: The panels show the electron density (left) and temperature (right) weekly time series (grey lines) together with the 20 min moving windows average (black lines). The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits. The average magnetic local time during the week is 1 p.m. for ascending phase and 4 a.m. for descending phase.

3.4.1.3 Swarm C

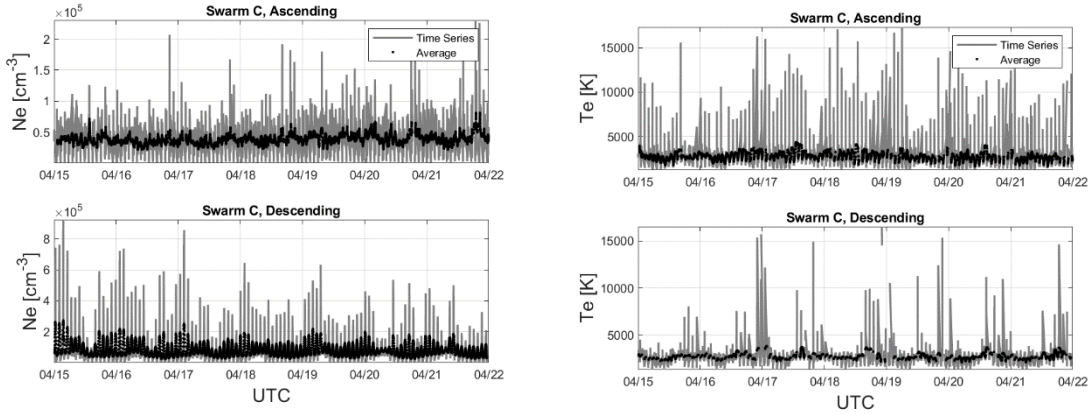


Figure 3-15: The panels show the electron density (left) and temperature (right) weekly time series (grey lines) together with the 20 min moving windows average (black lines). The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits. The average magnetic local time during the week is 5 a.m. for ascending phase and 5 p.m. for descending phase.

3.4.2 Plasma products latitudinal variations

3.4.2.1 Swarm A

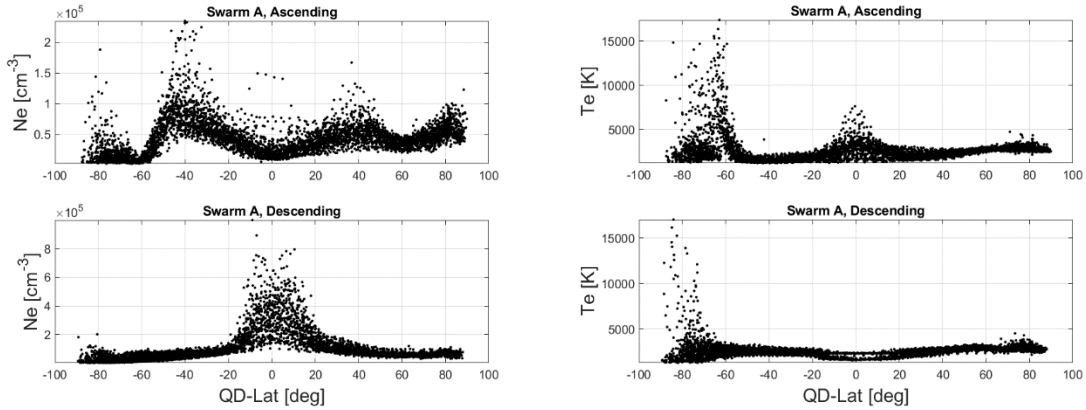


Figure 3-16: The panels shown the electron density (left) and temperature (right) profile as a function of QD Latitudes for the last week of operation. The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits.

3.4.2.2 Swarm B

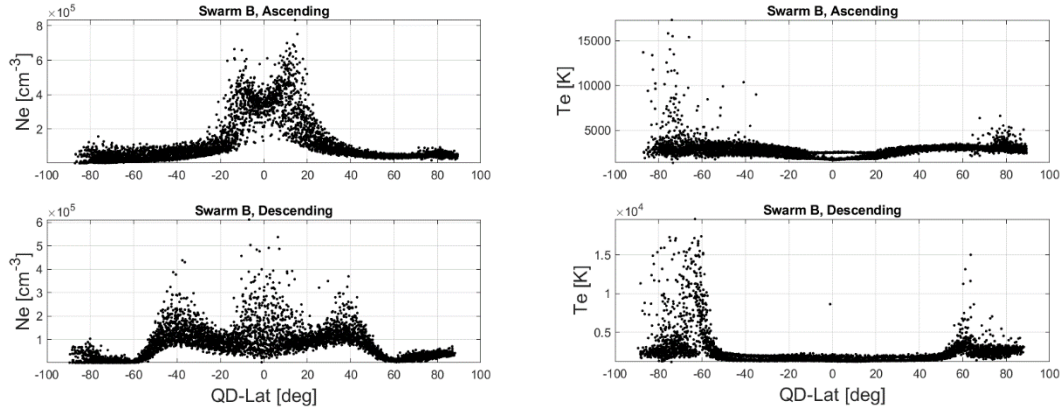


Figure 3-17: The panels shown the electron density (left) and temperature (right) profile as a function of QD Latitudes for the last week of operation. The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits.

3.4.2.3 Swarm C

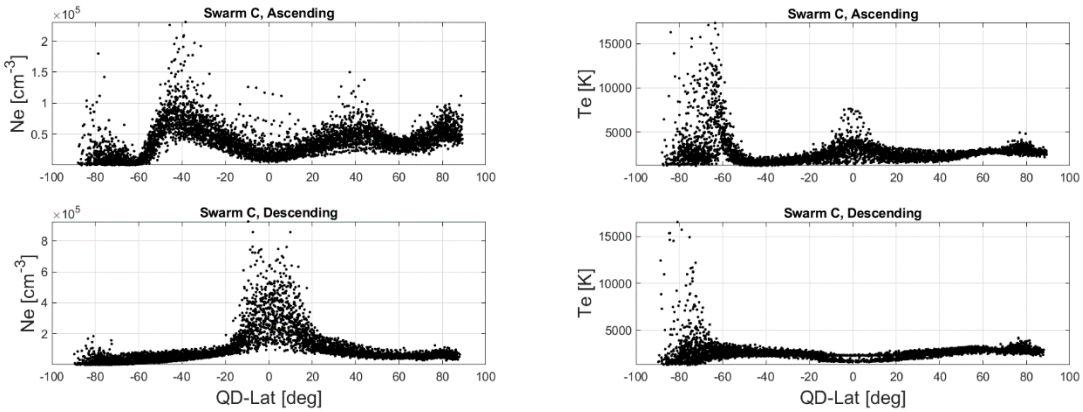


Figure 3-18: The panels shown the electron density (left) and temperature (right) profile as a function of QD Latitudes for the last week of operation. The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits.

4. Special Investigations

Nominal. Nothing to report.

End of Document