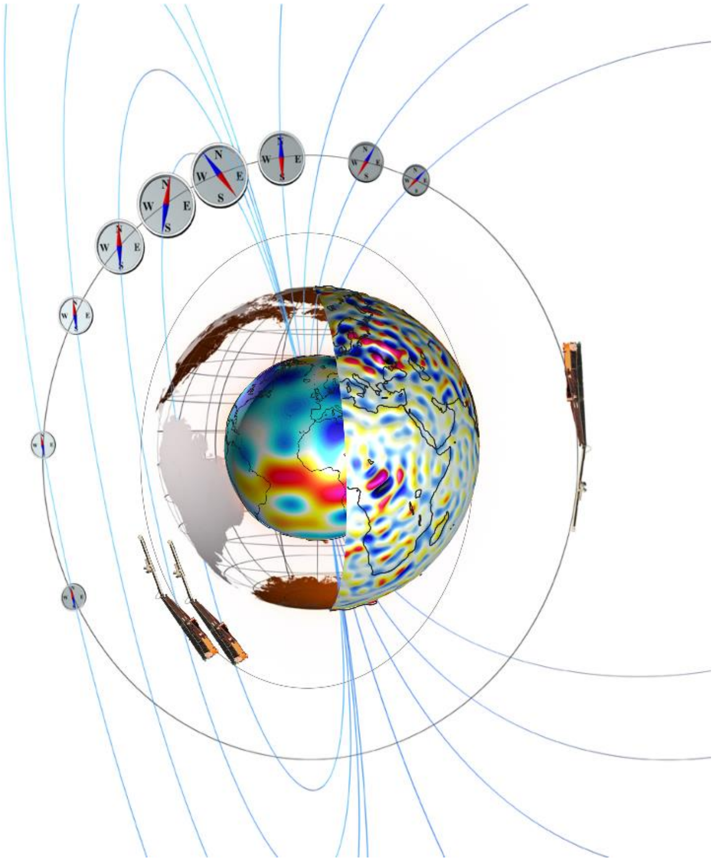
Swarm DISC Weekly Report 2019/47: 2019/11/18 - 2019/11/24



Abstract : This is the **Swarm Data Innovation and Science Cluster** (Swarm DISC) Weekly report on Swarm products quality, covering the period from 18 November to 24 November 2019.

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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	02 Dec 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 2, 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 on such 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 9th Swarm Data Quality Workshop (DQW#9) was held in Prague (Czech Republic) from 16 to 20 September 2019.

This workshop was focussed on Swarm payload performance, their product status and on the use of Swarm data to define a road map for identifying and selecting new Swarm data products and services, prioritizing future Swarm-related research activities, and for collecting inputs for the optimization of the orbital constellation in view of addressing a wide spectrum of applications.

The DQW#9 had eleven thematic sessions mainly related to:

- Swarm L1B data products and cal/val activities
- Internal/external field variations
- Swarm-based Multi-mission synergies
- Space Sciences/Weather perspectives and future challenges
- Time series analysis tools used in Swarm data processing

A complete summary of the recommendations based on the contributions from Swarm DQW#9 sessions will be published soon. More info on the Agenda and presentations are available at [RD.6].

1.2 Current Operational configuration of monitored data:

Processor	
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) ADF 0101
MPPF-CVQ	v03.07 (27/12/2018)

1.3 Recent evolutions:

The L1BOP v03.21 (delivered on 11/03/2019) and L2 Cat-2 OP v01.19 (delivered on 13/03/2019) contain only the porting to a newer operational system, Red Hat Enterprise Linux 7.5. No evolutions of the processor algorithms are included in these deliveries. The verification processor was concluded by both the Swarm PDGS team and Swarm Data quality team. During such verification process, the Swarm Data Quality Team detected few very small discrepancies while analysing the following products: STRxATT_1B (delta_q ~ 10^-9), ASMx_AUX_1B, MAGx_CA_1B, MAGx_HR_1B, MAGx_LR_1B (differences in the position within 1 cm and in the magnetic field components within 0.5 pT). In conclusion, all the discrepancies found are considered fully negligible (conclusion reached together with the PP providers). No issue is considered critical or blocking for the deployment in operations of these processors.

In the meantime, an improved version of the L1BOP (v03.22) has been delivered on 22/08/2019. The main evolutions of this operational processor consist in:

- MAGNET: Reading of ASMxBUR_0_ files to generate ASM 1Hz data during ASM burst mode sessions.
- ORBATT: Improving the combination of the three STR attitude quaternions into the combined attitude solution.
- PLASMA: Retrieving the information on the S/C position from MODx_SC_1B data product, instead of from MAGx_LR_1B and MAG_HR_1B data products.

  The PDGS Team will generate the test scenarios in order to compare their outputs with the ones from GMV. Then, the Data Quality Team will finalize the cross-verification of the processor.

* The production of the EEF product is temporarily suspended.

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 5.13.

[RD.4] 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.5] SW-RP-SER-GS-010_SPPA_SwarmWeeklyReport_201641_20161010_20161016.pdf

[RD.6] https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/activities/conferences/9th-data-quality-workshop

[RD.7] SW-RP-SER-GS-010_SPPA_SwarmWeeklyReport_201944_20191028_20191103.pdf

2. Summary of the observations

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

The ASM (Absolute Scalar Magnetometer) on board Swarm Bravo was commanded in burst mode on 24/11/2019 at 23:50:01 UTC for the entire calendar week 48.

2.2 Relevant observations of the week 47 (18/11 - 24/11)

During the monitored week the following events have been found:

- On day 23/11/2019, on S/C A B, C, we observe small anomalies on B_NEC – CHAOS6 model plots. It is caused by small geomagnetic storm, which occurred that day.
- On SC A on days 18/-24/11/2019, mean, VFM-ASM residuals values are out of thresholds, due to discrepancies between ASM and VFM.
- On SC B on days 18/-19/11/2019, mean, VFM-ASM residuals values are out of thresholds, due to discrepancies between ASM and VFM.

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. They are reported in tables in the sections below. In addition, some example plots are given 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 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.

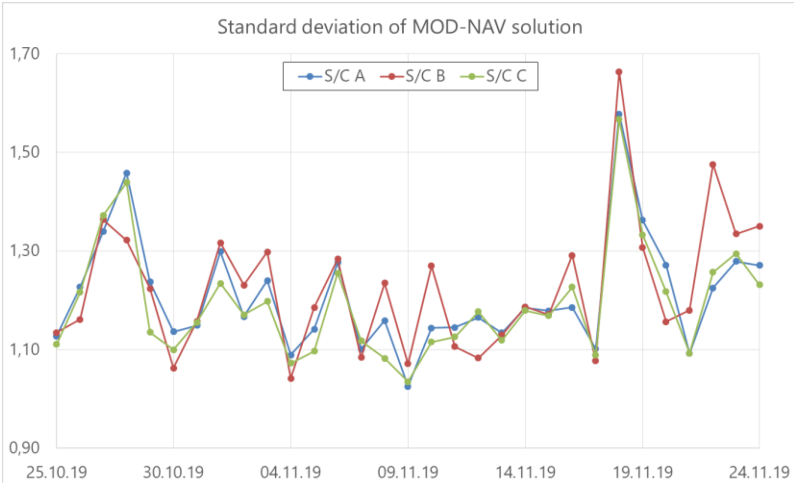

Figure 3-1: Plot of the standard deviation of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.

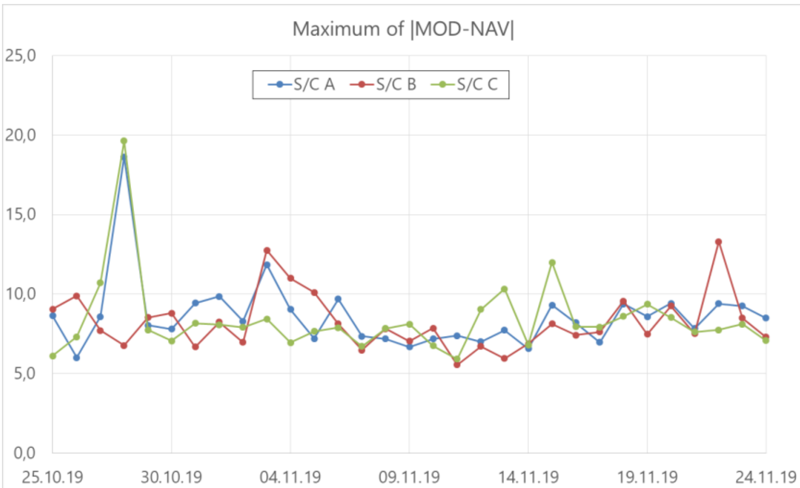

Figure 3-2: Plot of the maximum difference of the absolute value of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.

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 (Chaos6).

3.3.1 VFM-ASM anomaly

- S/C A – violation of:
  - VFM-ASM residuals threshold on 18/11, 19/11, 20/11, 21/11, 22/11, 23/11, 24/11;
  - mean value of residuals threshold on 18/11, 19/11, 20/11, 21/11, 22/11, 23/11, 24/11;
- S/C B – violation of:
  - VFM-ASM residuals threshold on 18/11;
  - standard deviation of residuals threshold on 18/11, 19/11.

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.

Data gap in Figure 3-4 is due to the ASM operating in burst mode on board Swarm Bravo (see [RD.7] for more details).

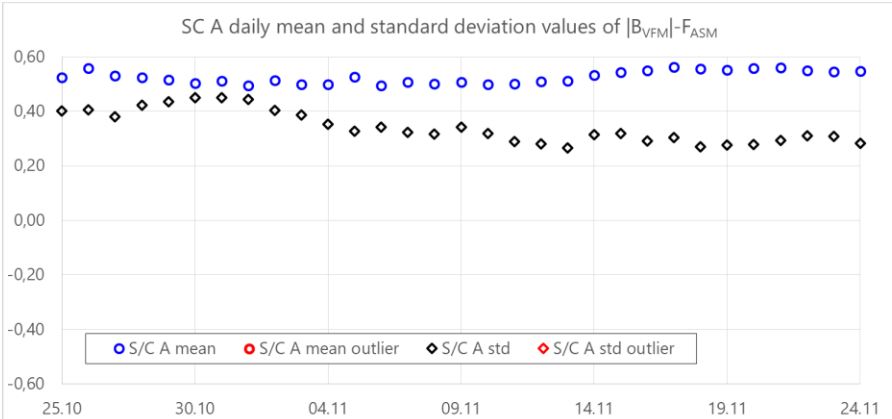

Figure 3-3: Daily mean and standard deviation values of ASM-VFM residuals (defined as $dF=|B_{VFM}|-F_{ASM}$) for S/C A.

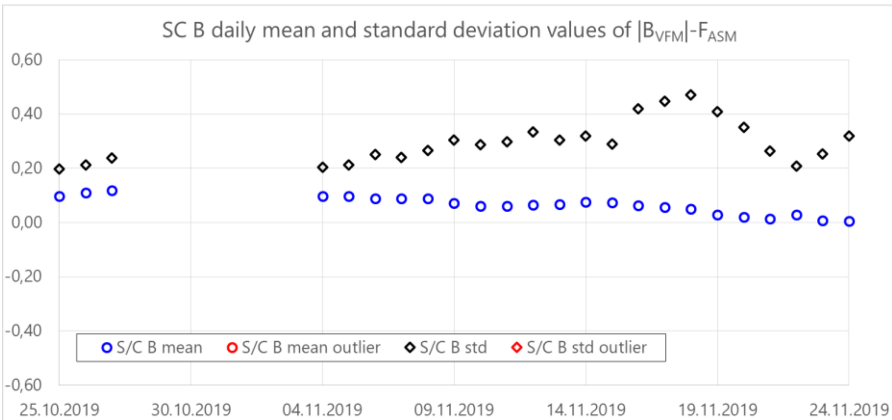

Figure 3-4: Daily mean and standard deviation values of ASM-VFM residuals (defined as $dF=|B_{VFM}|-F_{ASM}$) for S/C B.

3.3.1.2 Swarm A

The daily peak-to-peak difference around the week stays within [-0,44 - 1,25] nT. Below follow two plots of such differences for current week (Figure 3-5).

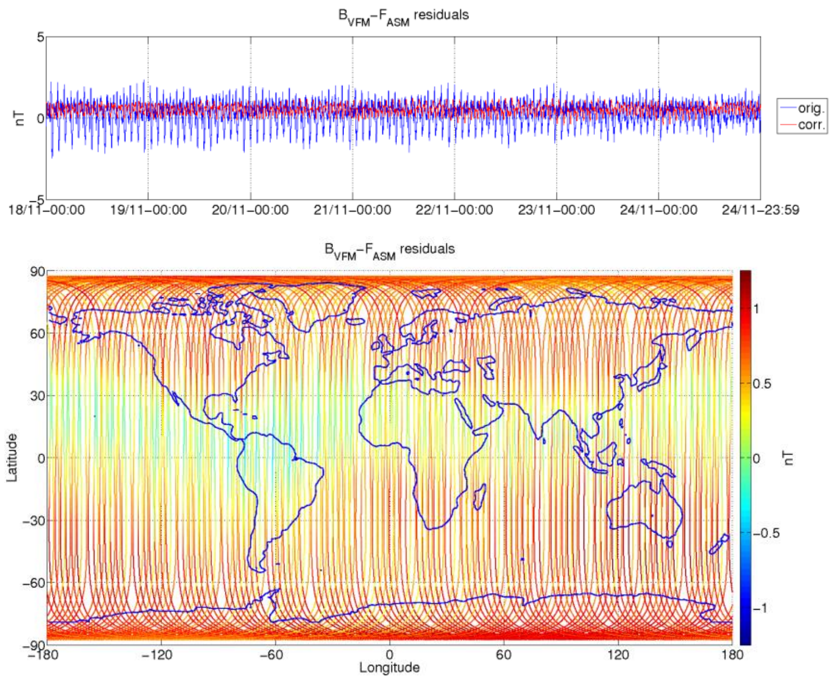

Figure 3-5: ASM-VFM residuals for S/C A, during monitoring period 18/11-24/11. In top figure are plotted: difference between |B_VFM| and F_ASM (without dB_Sun correction) (blue colour), and the residuals with dB_Sun corrections (red colour). In bottom figure residuals are presented on the world map.

3.3.1.3 Swarm B

The daily peak-to-peak difference around the week stays within [-0,82 - 1,06] nT. Below follow two plots of such differences for current week (Figure 3-6).

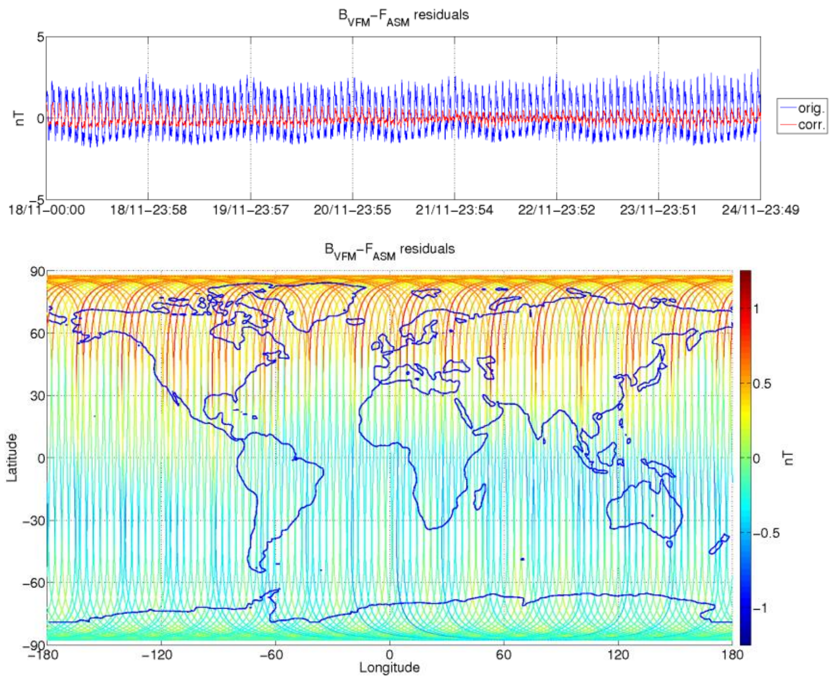

Figure 3-6: ASM-VFM residuals for S/C B, during monitoring period 18/11-24/11. In top figure are plotted: difference between |B_VFM| and F_ASM (without dB_Sun correction) (blue colour), and the residuals with dB_Sun corrections (red colour). In bottom figure residuals are presented on the world map.

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 47 for S/C A can be seen in Figure 3-7 below.

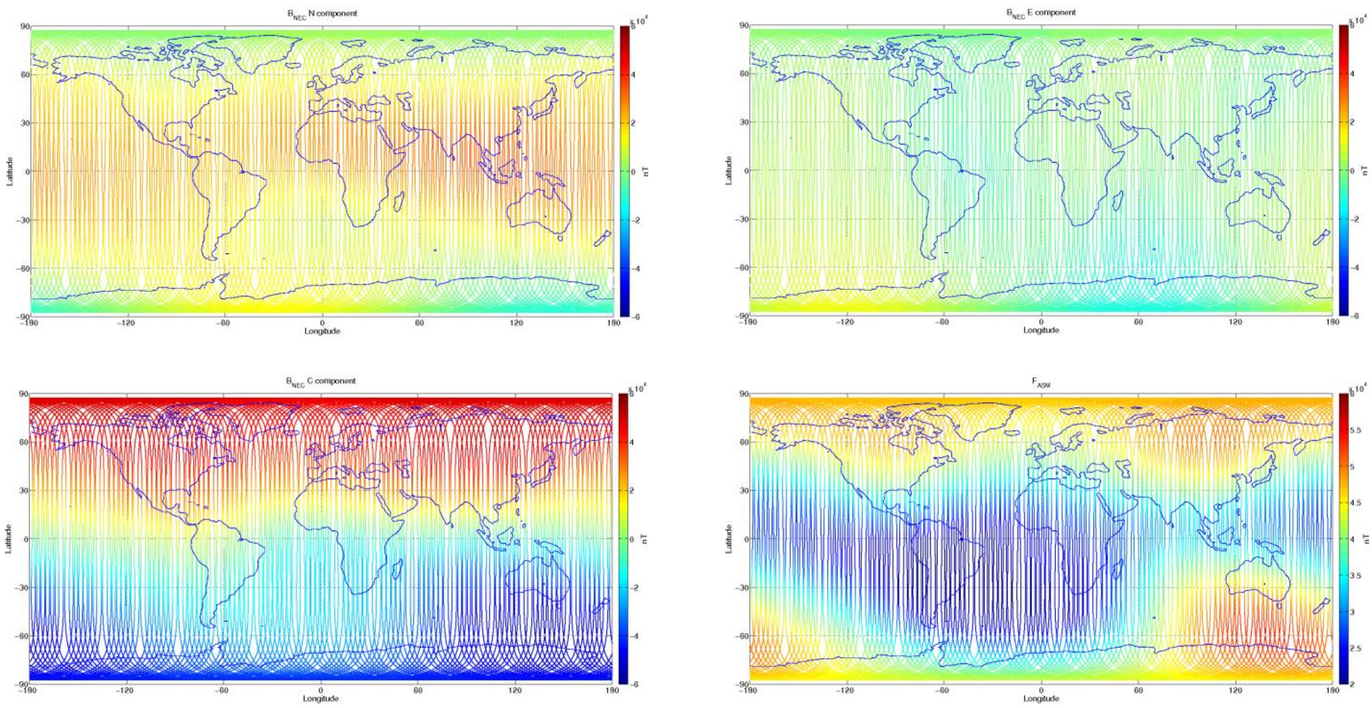

Figure 3-7: S/C A, world map plots of the geomagnetic field and components measured during monitoring period 18/11-24/11. From top to bottom: B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement, F-magnetic field from ASM measurement.

3.3.4.2 Swarm B

Map plots of magnetic field measurement for week 47 for S/C B can be seen in Figure 3-8 below.

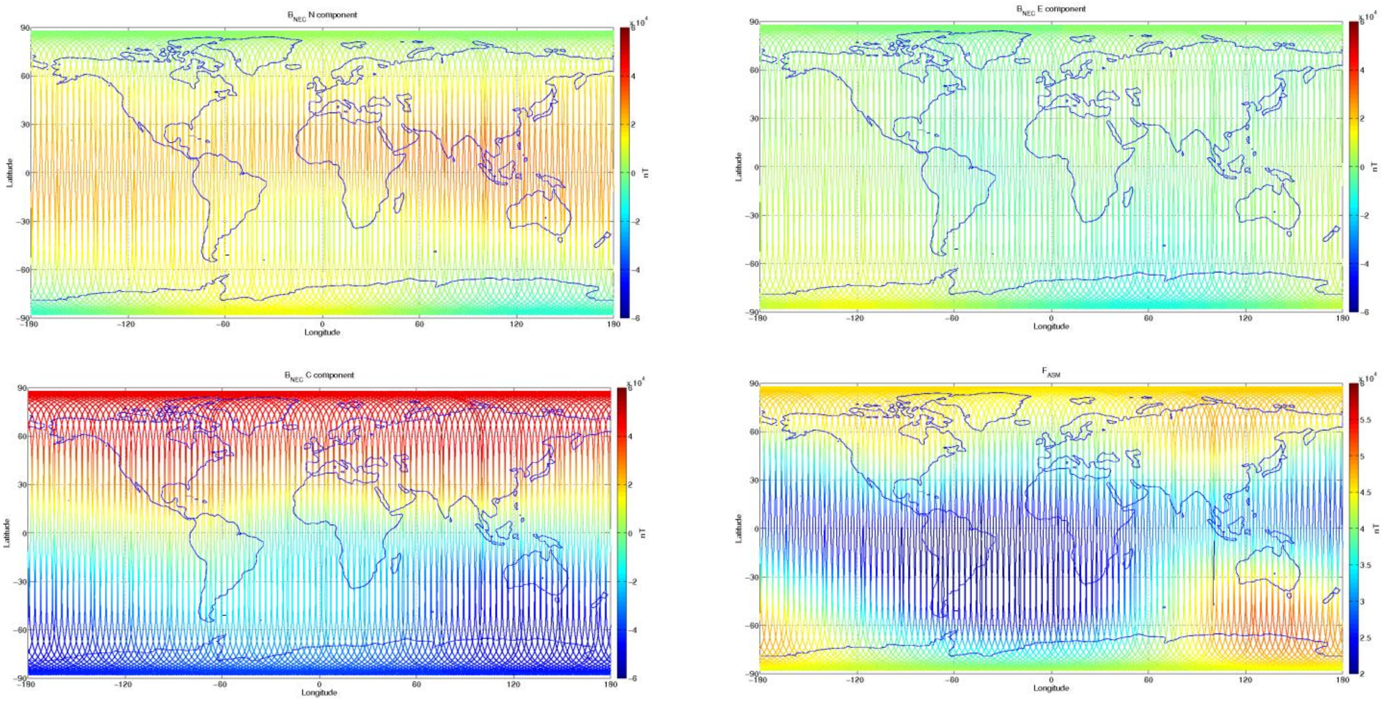

Figure 3-8: S/C B, world map plots of the geomagnetic field and components measured during monitoring period 18/11-24/11. From top to bottom: B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement F-magnetic field from ASM measurement

3.3.4.3 Swarm C

Map plots of magnetic field measurement for week 47 for S/C C can be seen in Figure 3-9.

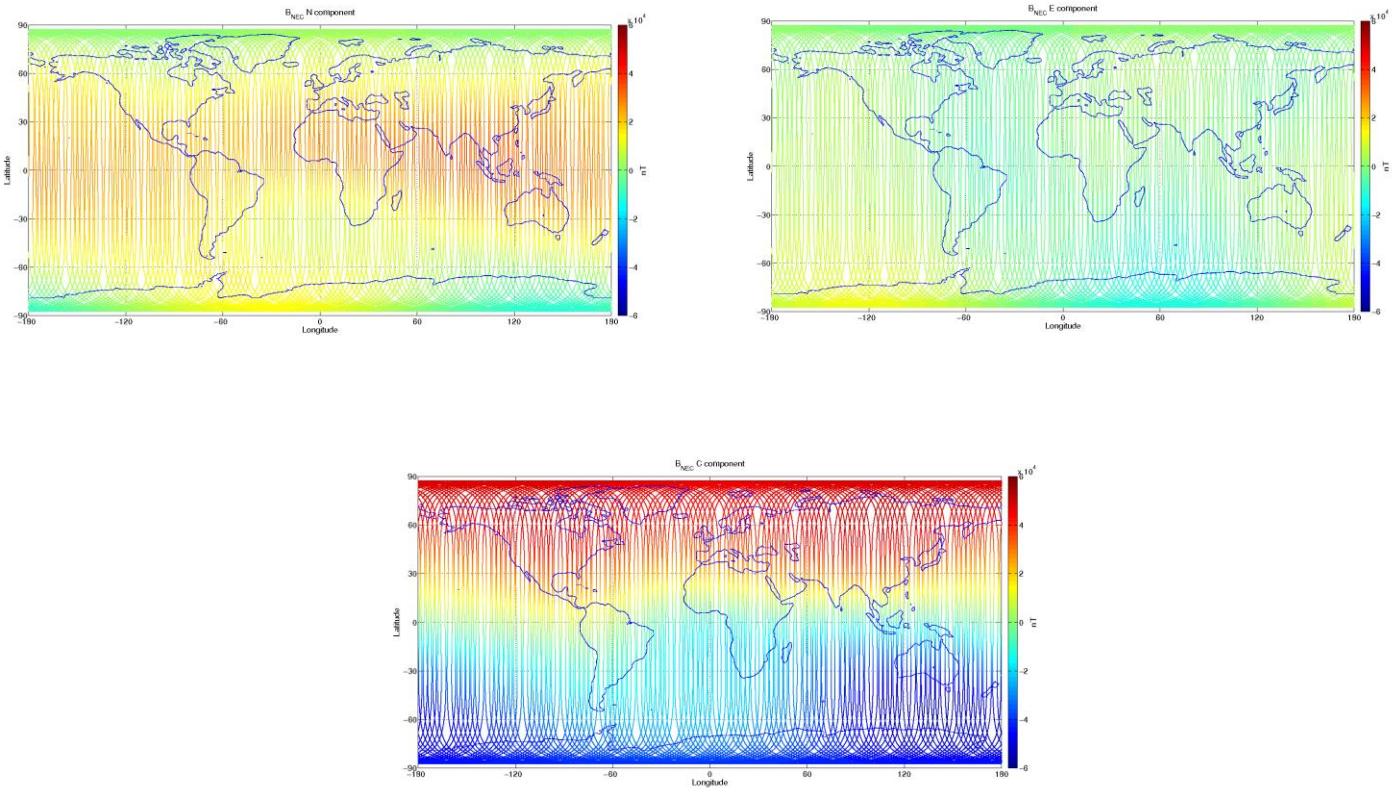

Figure 3-9: S/C C, world map plots of the geomagnetic field and components measured during monitoring period 18/11-24/11. From top to bottom: B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement

3.3.5 B_{NEC} vs Chaos6 model residuals

The magnetic field measurement is compared to magnetic field estimated from the Chaos6 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 and 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.4]).

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

On day 23/11/2019, on S/C A B, C, we observe small anomalies on B_NEC – CHAOS6 model plots. It is caused by small geomagnetic storm, which occurred that day.

3.3.5.1 Swarm A

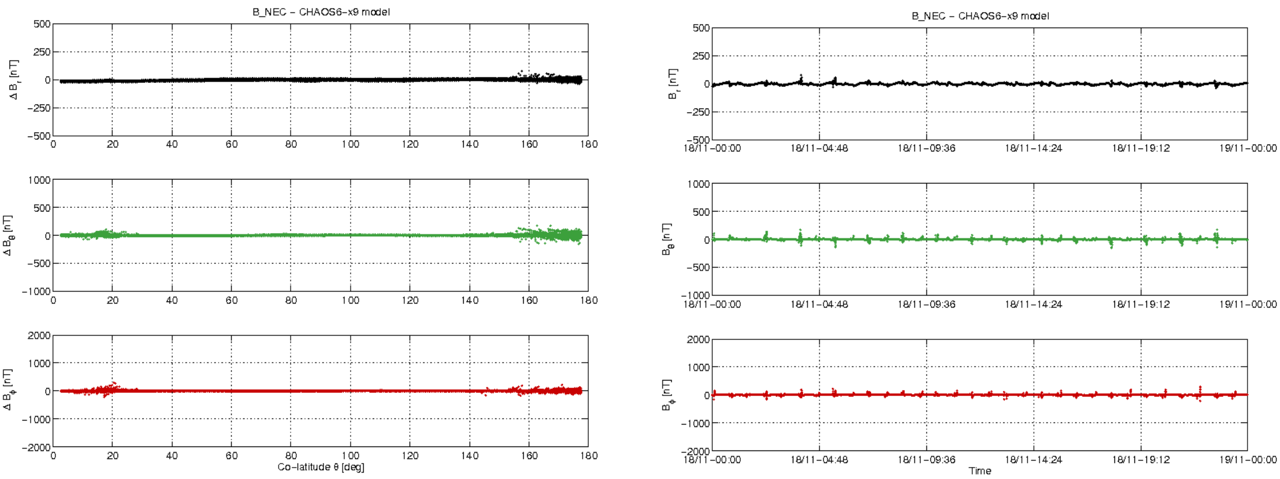

Figure 3-10: S/C A day 18.11: time series of $B_{NEC} - B_{Chaos}$ residuals (right) and B_{NEC} - B_{Chaos} vs colatitude (left).

3.3.5.2 Swarm B

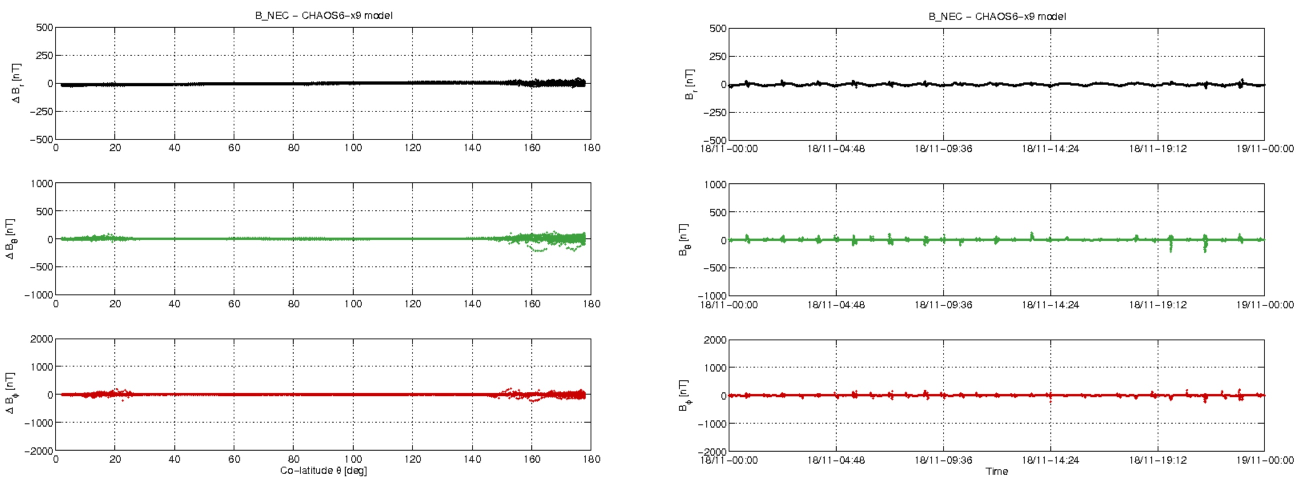

Figure 3-11: S/C B day 18.11: time series of B_{NEC} – B_{Chaos} residuals (right) and B_{NEC} - B_{Chaos} vs colatitude (left).

3.3.5.3 Swarm C

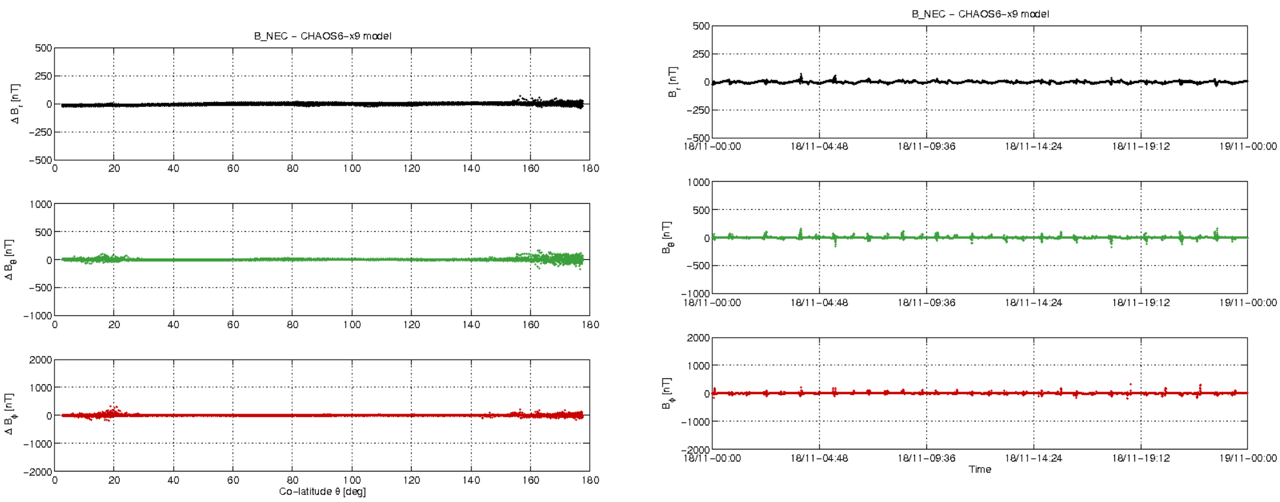

Figure 3-12: S/C C day 18.11: time series of B_{NEC} – B_{Chaos} residuals (right) and B_{NEC} - B_{Chaos} vs colatitude (left)

3.4 Plasma Products

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

Figures from Figure 3-13 to Figure 3-15 show 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 from 0.5s 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. Information on the local magnetic time is reported in the captions.

Figures from Figure 3-16 to Figure 3-18 show 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 analyses are useful to study the dependence of the variables on the QD magnetic coordinate system.

These analyses 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 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

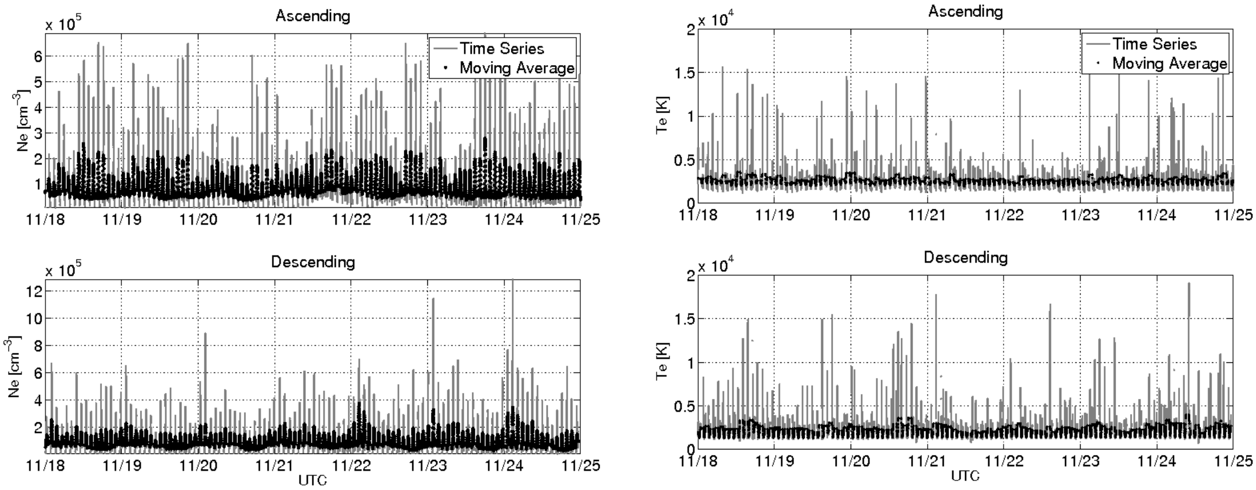

Figure 3-13: The panels show the electron density (left) and temperature (right) weekly time series (grey lines) together with the 20 min moving windows average (black lines). The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits. The average magnetic local time during the week is 10 a.m. for ascending phase and 10 p.m. for descending phase.

3.4.1.2 Swarm B

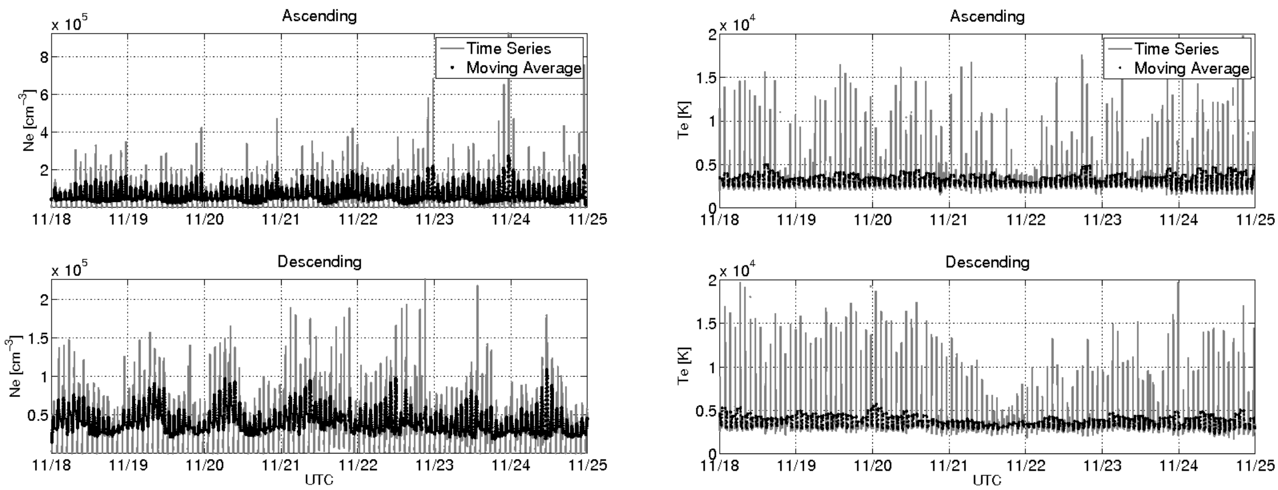

Figure 3-14: The panels show the electron density (left) and temperature (right) weekly time series (grey lines) together with the 20 min moving windows average (black lines). The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits. The average magnetic local time during the week is 7 a.m. for descending phase and 7 p.m. for ascending phase.

3.4.1.3 Swarm C

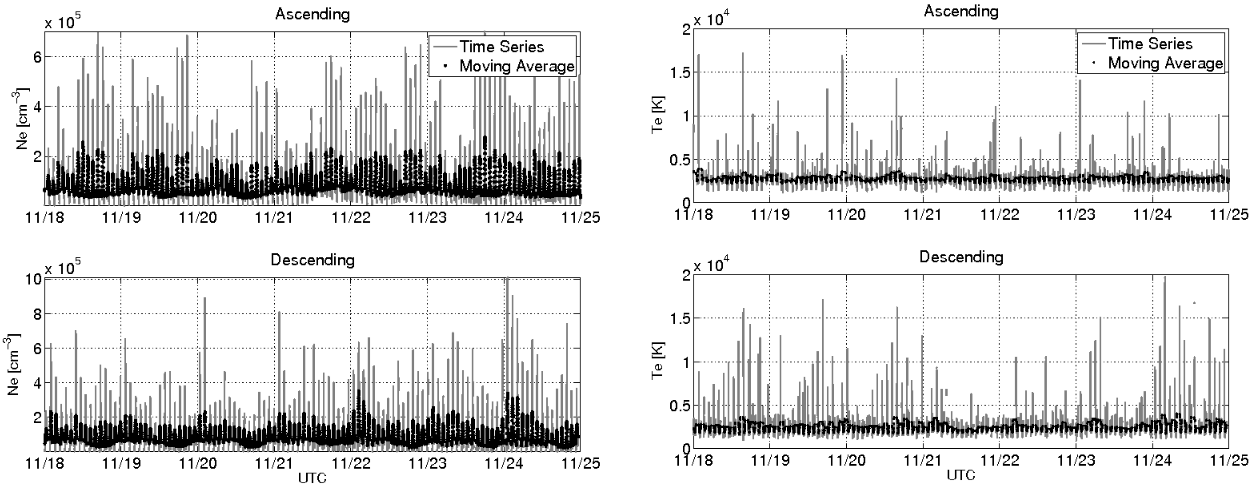

Figure 3-15: The panels show the electron density (left) and temperature (right) weekly time series (grey lines) together with the 20 min moving windows average (black lines). The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits. The average magnetic local time during the week is 10 a.m. for ascending phase and 10 p.m. for descending phase.

3.4.2 Plasma products latitudinal variations

3.4.2.1 Swarm A

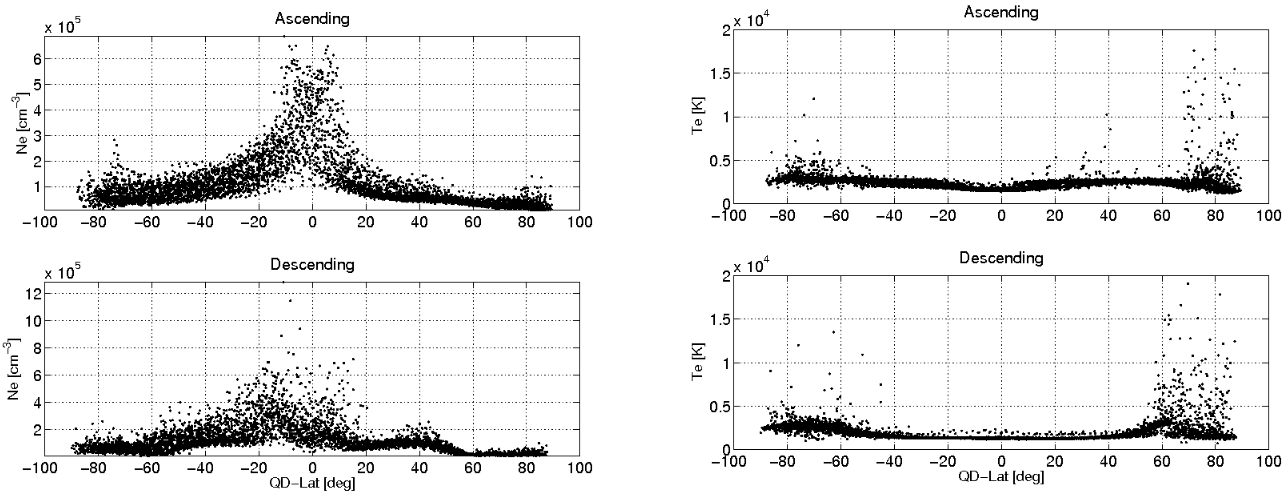

Figure 3-16: The panels shown the electron density (left) and temperature (right) profile as a function of QD Latitudes for the last week of operation. The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits.

3.4.2.2 Swarm B

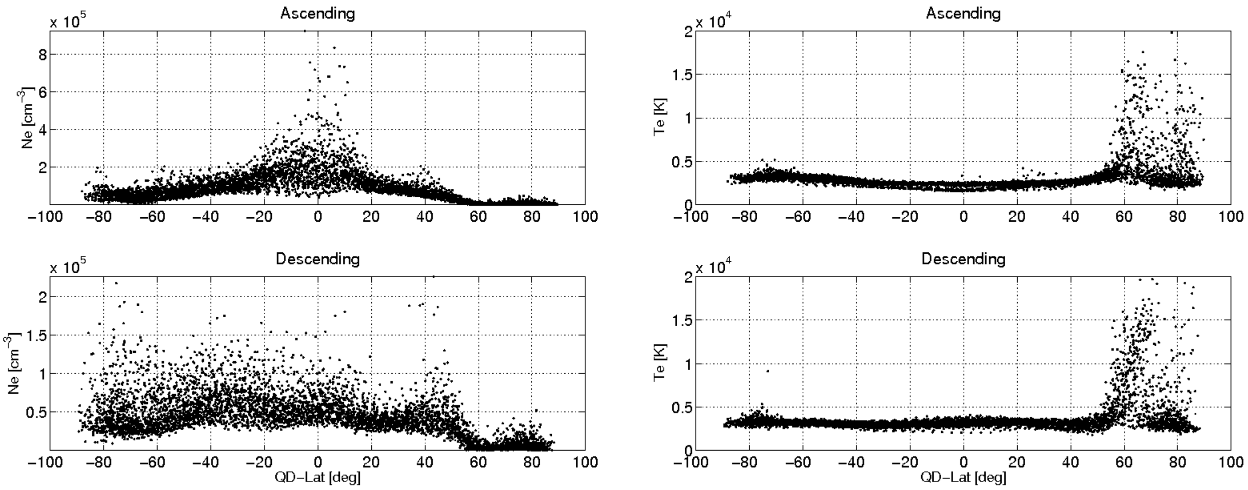

Figure 3-17: The panels shown the electron density (left) and temperature (right) profile as a function of QD Latitudes for the last week of operation. The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits.

3.4.2.3 Swarm C

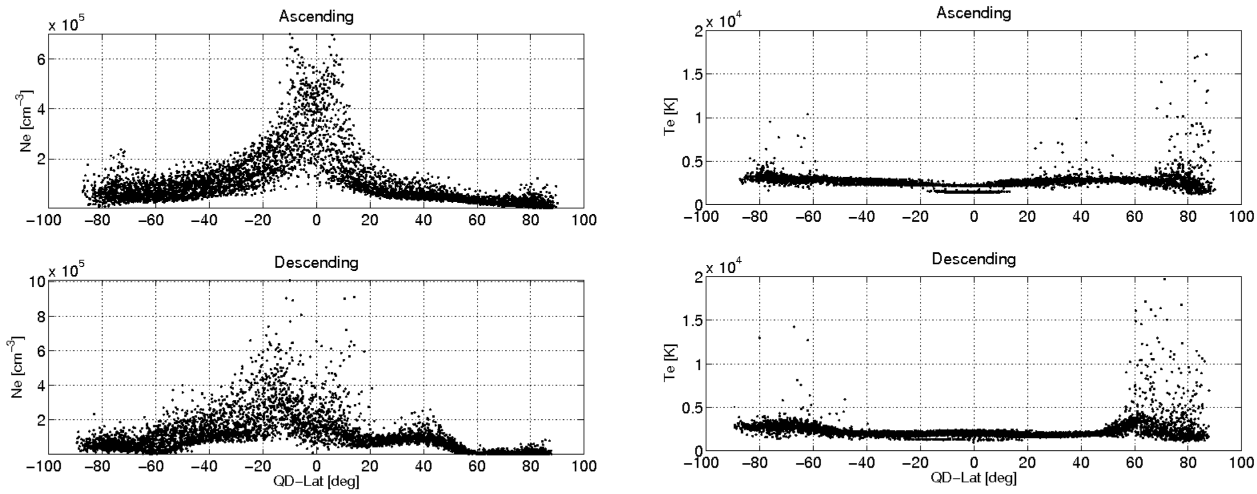

Figure 3-18: The panels shown the electron density (left) and temperature (right) profile as a function of QD Latitudes for the last week of operation. The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits.

4. Special Investigations

Nothing to report.

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