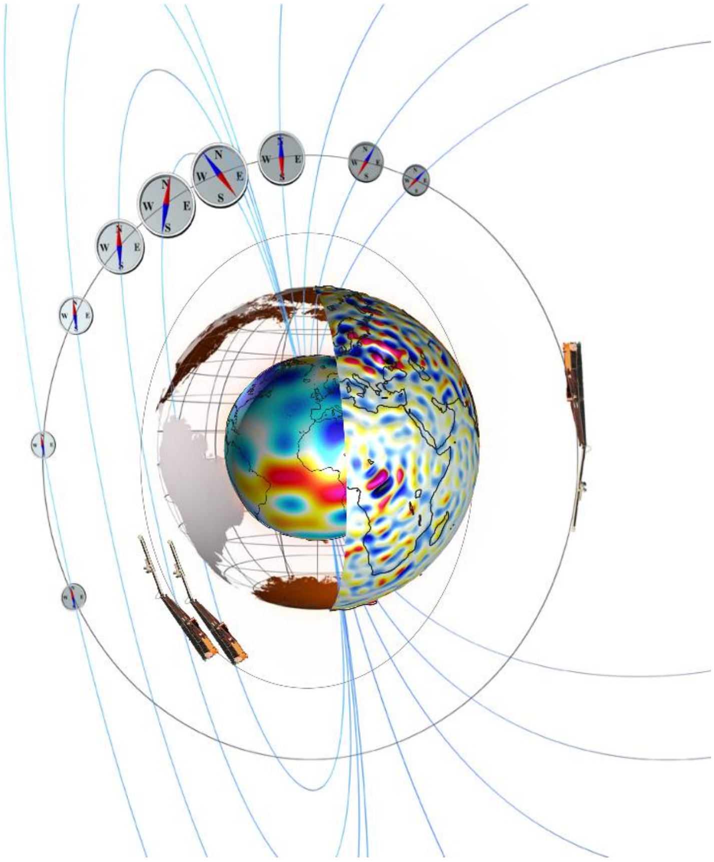
Swarm DISC Weekly Report 2022/41: 2022/10/10 - 2022/10/16



Abstract : This is the **Swarm Data Innovation and Science Cluster** (Swarm DISC) Weekly report on Swarm products quality, covering the period from 10 October to 16 October 2022.

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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	30 Nov 2022	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. 01].

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. 02], 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. 03].

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 12th Swarm Data Quality Workshop was hosted by the Swedish Institute of Space Physics (IRFU) in Uppsala, Sweden, from 10 to 14 October 2022. Thanks to the participation of more than 150 scientists (in presence and remotely) from different institutions in Europe, America and Asia, the event was a great success.

The DQW#12, structured in 10 thematic sessions including talks and dedicated time slots for discussions, was instrumental in addressing the processing and use of Swarm data and defining a road map for future activities.
The main topics addressed during the workshop were related to:

- collecting feedback about new Swarm dataset generated with an improved version of L1B and L2-Cat2 operational processors
- identifying possible new Swarm data products and services, with particular attention to Space Weather applications
- promoting synergies with other satellite missions
- discussing on future Swarm-based science applications and orbital constellation evolution

More information on the Swarm DQW#12 outcomes, summary and recommendations will be published soon.

1.2 Current Operational configuration of monitored data:

Processor	
Name	**Version**
L1BOP	v3.24p4
L2-Cat2	v01.20
Products	
Name	**Baseline**
L0 inputs	02
L1B MAGNET and PLASMA	06
L1B ORBATT and ACCELE	05
L2-Cat2 EEF	02
L2-Cat2 IBI, FAC and TEC	04
Others	
Input auxiliary files	S/C A, CCDB 0028 (27/09/2022) S/C B, CCDB 0028 (27/09/2022) S/C C, CCDB 0029 (27/09/2022)
MPPF-CVQ	v03.13 (18/03/2022)

1.3 Recent evolutions:

An improved version for both L1B and L2 (FAC, IBI, and TEC) Operational Processors was transferred into operation on 28/09/2022.

The main improvements introduced in L1B data processing chain are:

- Improved thruster activation information
- New Flags_q parameter
- Removed duplicated timestamp in GPS RINEX files
- Improved thermal model for Inter Boresight Angle (IBA) variation
- Improved dB_Sun and new dF_Sun stray fields
- Improved F_ASM data processing during Burst Mode sessions
- Production of MAGNET data when no VFM data are available
- Usage of POD as input for MAGNET
- New LP calibration parameter
- Improved Flags for Plasma products

Please note that the L1B data improvements have a negligible impact on L2 IBI, FAC and TEC products. Moreover, the porting to an updated operational system was performed for both L1B and L2 Operational processors, without any impact on Swarm L1B and L2 data content. For more information please refer to the Technical Note [RD .05].

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. 01] Sensor Performance, Products and Algorithms (SPPA), PGSI-GSOP-EOPG-TN-05-0025. Version 2.3.

[RD. 02] Swarm MPPF-CVQ Monitoring Baseline Document, ST-ESA-SWARM-MBD-0001, Issue 1.7.

[RD. 03] Swarm Level 1B Product Definition, SW-RS-DSC-SY-0007, Issue 5.23.

[RD. 04] 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. 05] https://earth.esa.int/documents/10174/1514862/Swarm-L1B-and-L2-operational-processors.pdf

2. Summary of the observations

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

• A collision avoidance manoeuvre was executed on Swarm Alpha on 10/10/2022 at 02:57 UT. The manoeuvre was planned to avoid the collision with the Electron satellite kick stage. Consequently, the quality of the magnetic data was affected and the ASM-VFM difference for Swarm Alpha went out of threshold during the manoeuvre (see Section 3.3.1.2 Figure 3-5).

• A Constellation maintenance manoeuvre was executed on Swarm Charlie on 11/10/2022 at 14:58 UT. The manoeuvre was planned to keep the pair separation between Swarm Alpha and Swarm Charlie below 10 seconds. Consequently, the quality of the magnetic data was affected during the manoeuvre.

• On 10/10/2022 there was an anomaly on the telemetry of the Swarm-A causing a small data gap (see Section 3.1).

2.2 Relevant observations of the week 41 (10/10 - 16/10)

During the monitored week no events have been found.

3. Routine Quality control

3.1 Gaps analysis

- 10th October:

  Swarm-A ASM data gap from 05:09:46 to 05:09:51

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. 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 and Figure 3-2 one can see the statistics of the differences between MOD and on-board solution positions for S/C A, B and C respectively. 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.

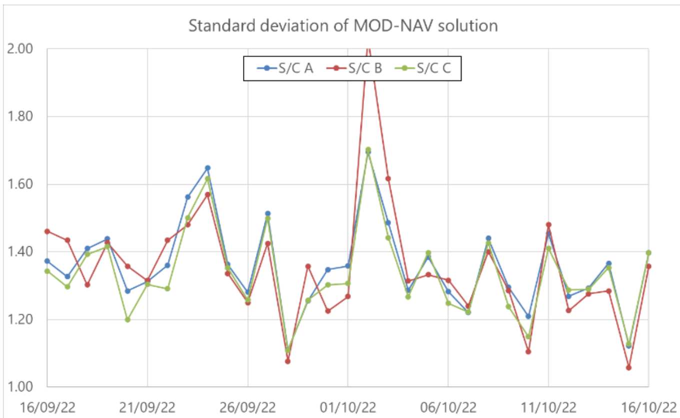

Figure 3-1: Plot of the standard deviation of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.

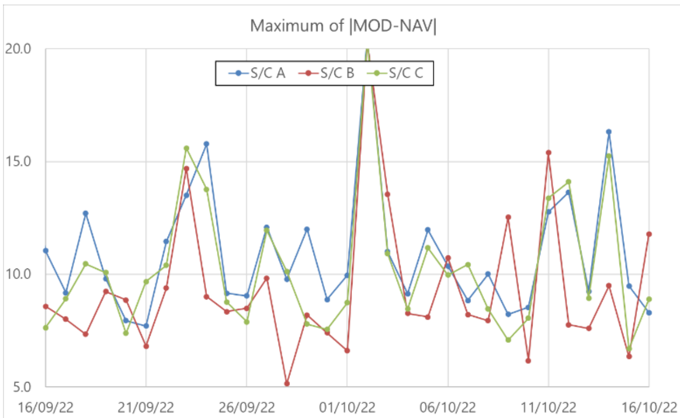

Figure 3-2: Plot of the maximum difference of the absolute value of the difference between MOD and NAV solutions for all satellites. Plot covers last month of operation.

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 (Chaos7).

3.3.1 VFM-ASM anomaly

- S/C A – violation of:
  - VFM-ASM residuals threshold on 10/10;
  - standard deviation of residuals threshold on 10/10.
- S/C B – no violation of VFM-ASM residual 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. The change in data trend observed in both graphics since 24/09/2022 is related to the improvement of the dB_Sun correction implemented within the new L1B processor on 28/09/2022 (see section 1.3), which updates are effective starting from the 24/09/2022.

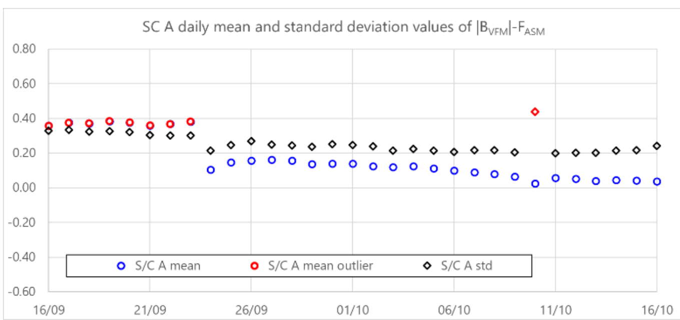

Figure 3-3: Daily mean and standard deviation values of ASM-VFM residuals (defined as $dF=|B_{VFM}|-F_{ASM}$) for S/C A.

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 [-11.32 - 0.61] nT. Below follow two plots of such differences for current week (Figure 3-5).

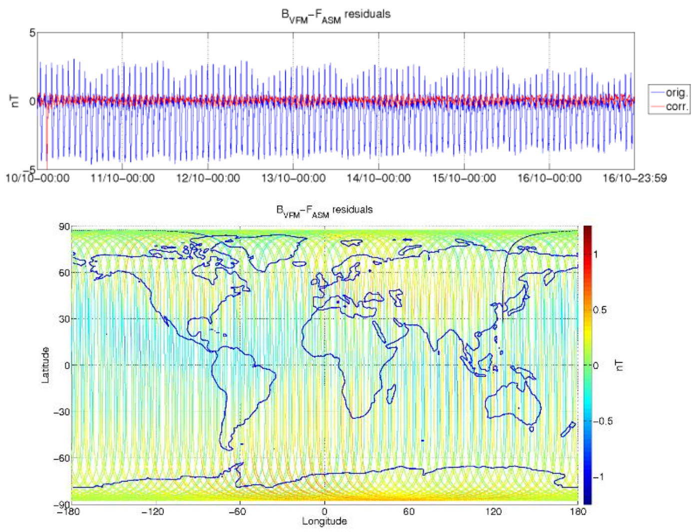

Figure 3-5: ASM-VFM residuals for S/C A, during monitoring period 10/10-16/10. In top figure are plotted: difference between |B_VFM| and F_ASM (without dB_Sun correction) (blue colour), and the residuals with dB_Sun corrections (red colour). In bottom figure residuals are presented on the world map.

3.3.1.3 Swarm B

The daily peak-to-peak difference around the week stays within [-0.62 - 0.71] nT. Below follow two plots of such differences for current week (Figure 3-6).

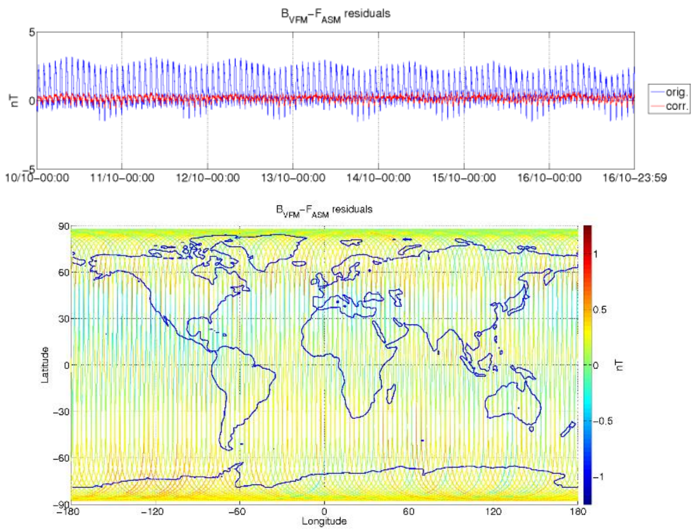

Figure 3-6: ASM-VFM residuals for S/C B, during monitoring period 10/10-16/10. In top figure are plotted: difference between |B_VFM| and F_ASM (without dB_Sun correction) (blue colour), and the residuals with dB_Sun corrections (red colour). In bottom figure residuals are presented on the world map.

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

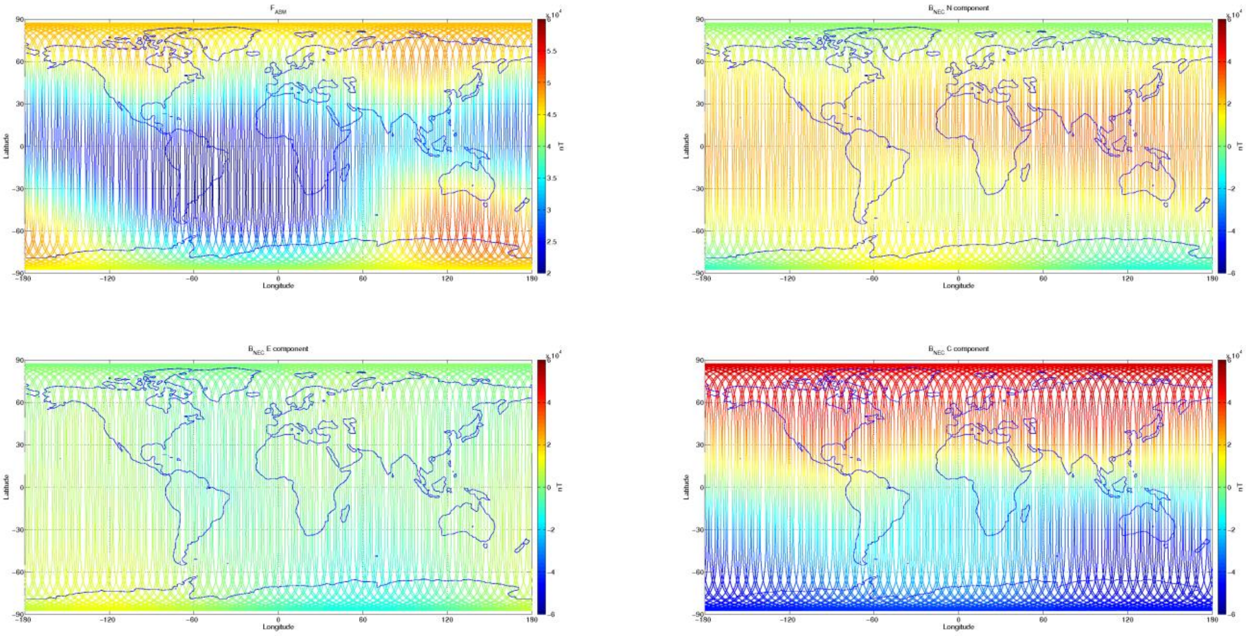

Figure 3-7: S/C A, world map plots of the geomagnetic field and components measured during monitoring period 10/10-16/10. From top to bottom: F-magnetic field from ASM measurement, B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement.

3.3.4.2 Swarm B

Map plots of magnetic field measurement for week 41 for S/C B can be seen in Figure 3-8 below.

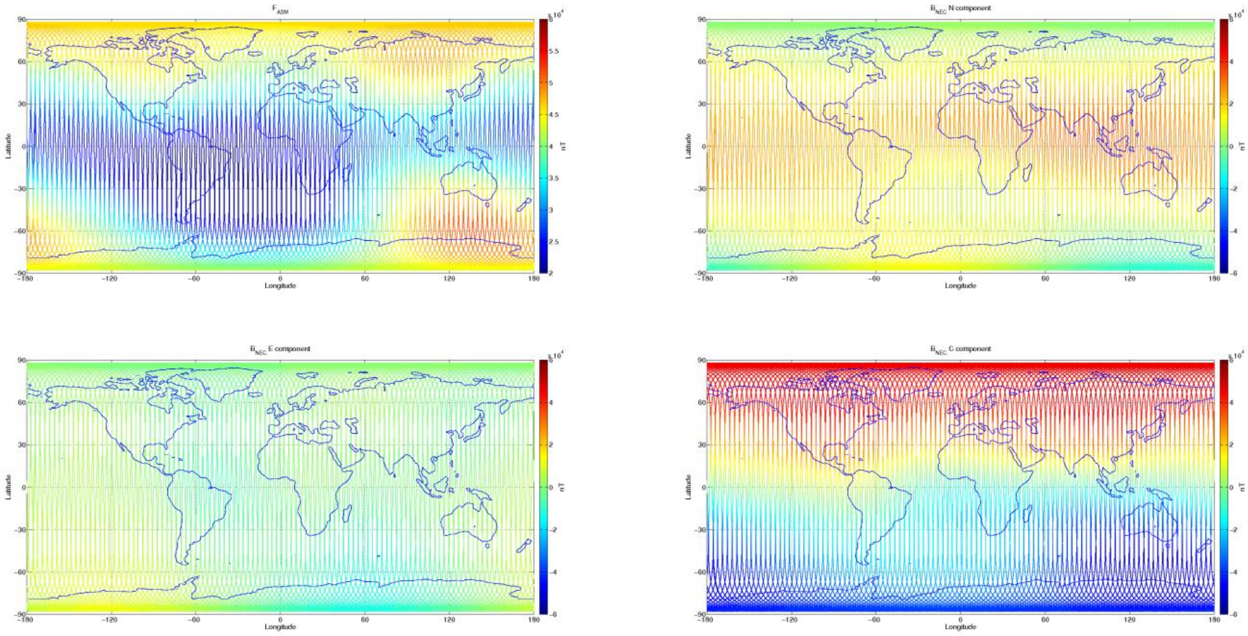

Figure 3-8: S/C B, world map plots of the geomagnetic field and components measured during monitoring period 10/10-16/10. From top to bottom: F-magnetic field from ASM measurement, B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement.

3.3.4.3 Swarm C

Map plots of magnetic field measurement for week 41 for S/C C can be seen in Figure 3-9.

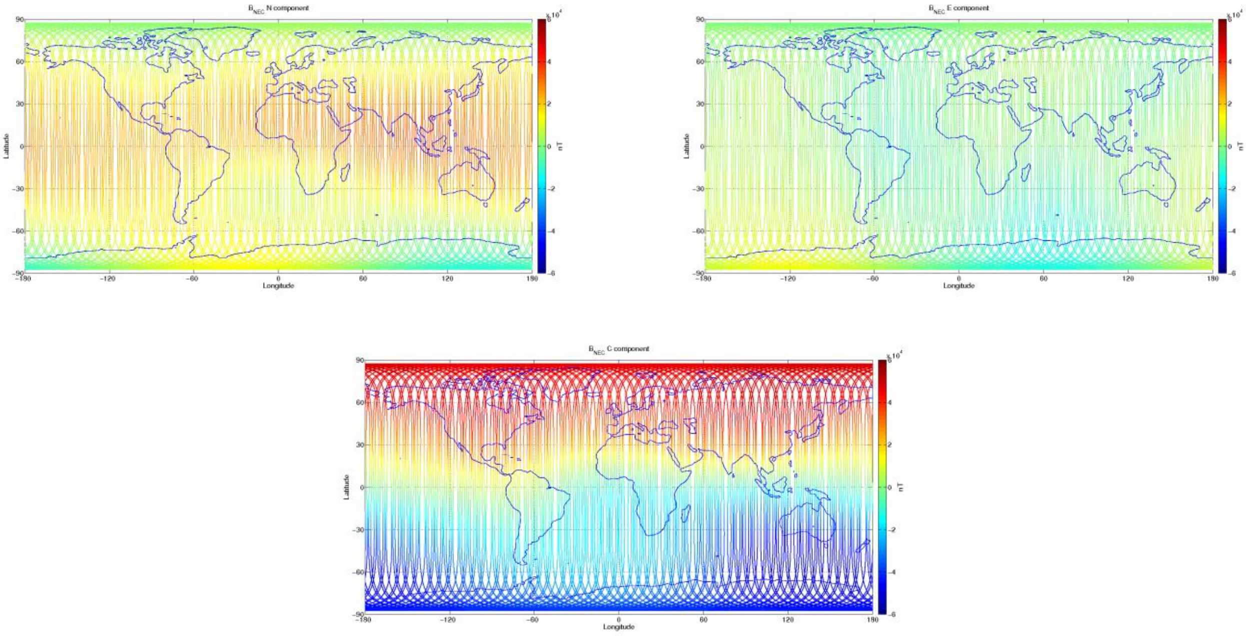

Figure 3-9: S/C C, world map plots of the geomagnetic field and components measured during monitoring period 10/10-16/10. From top to bottom: B_{NEC} components (North, East, and Centre) of magnetic field from VFM measurement.

3.3.5 B_{NEC} vs Chaos7 model residuals

The magnetic field measurement is compared to magnetic field estimated from the Chaos7 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. 04]).

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.

3.3.5.1 Swarm A

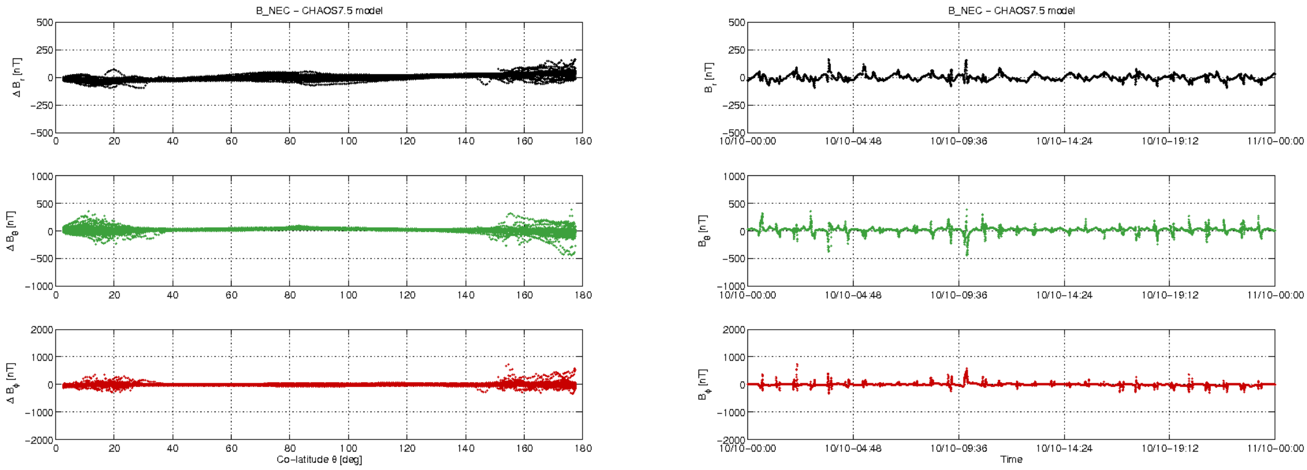

Figure 3-10: S/C A day 10/10: time series of $B_{NEC} – B_{Chaos}$ residuals (right) and B_{NEC} - B_{Chaos} vs colatitude (left).

3.3.5.2 Swarm B

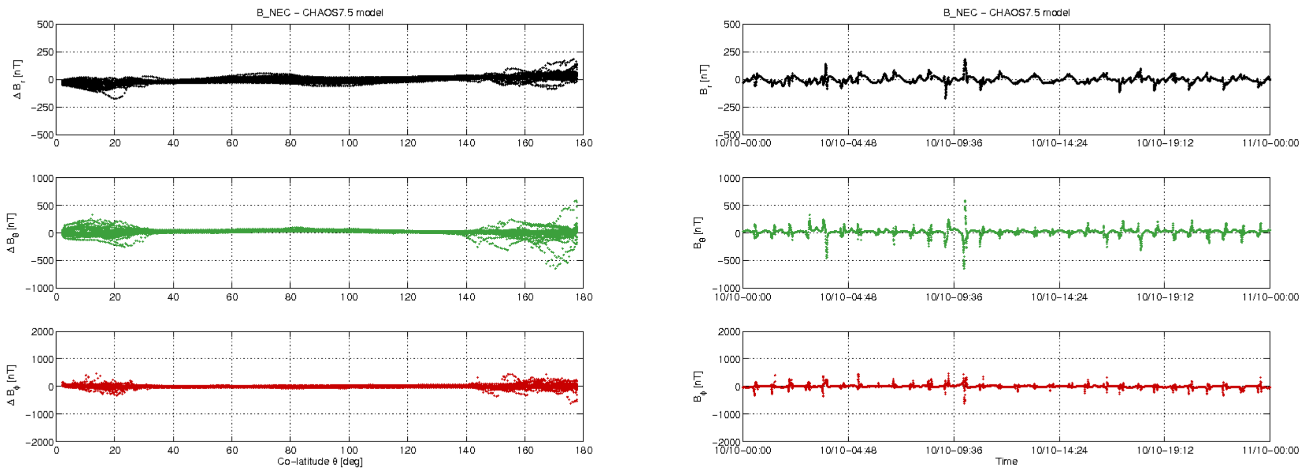

Figure 3-11: S/C B day 10/10: time series of $B_{NEC} – B_{Chaos}$ residuals (right) and B_{NEC} - B_{Chaos} vs colatitude (left).

3.3.5.3 Swarm C

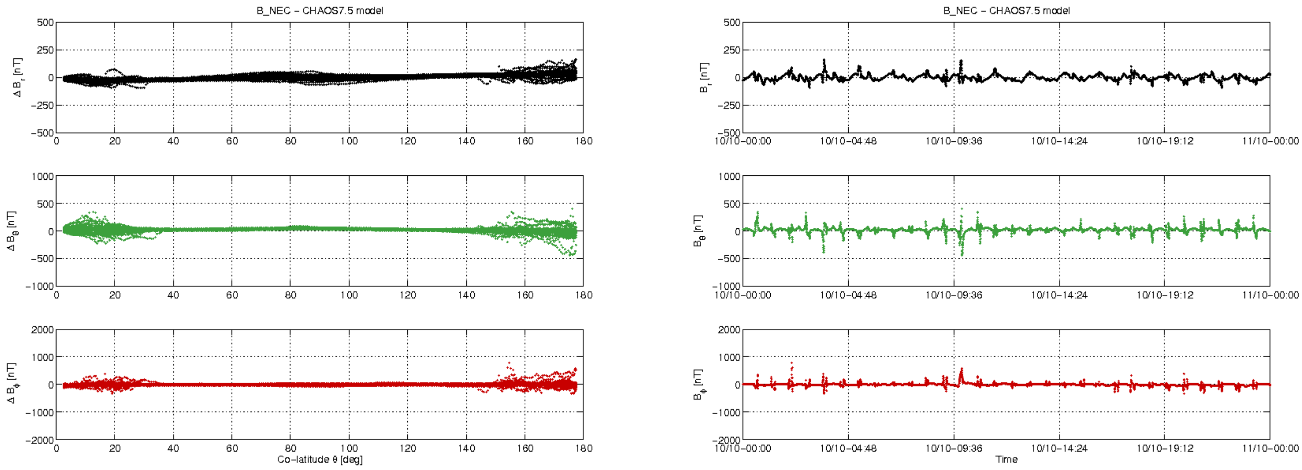

Figure 3-12: S/C C day 10/10: time series of $B_{NEC} - B_{Chaos}$ residuals (right) and $B_{NEC} - B_{Chaos}$ vs colatitude (left)

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 thousand 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

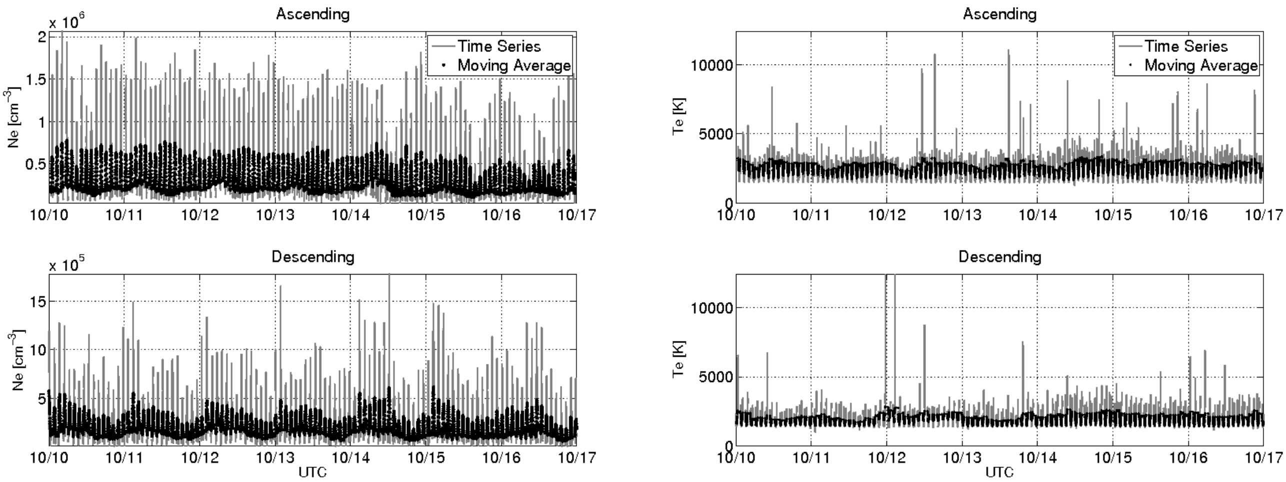

Figure 3-13: The panels show the electron density (left) and temperature (right) weekly time series (grey lines) together with the 20 min moving windows average (black lines). The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits. The average magnetic local time during the week is 11 a.m. for ascending phase and 11 p.m. for descending phase.

3.4.1.2 Swarm B

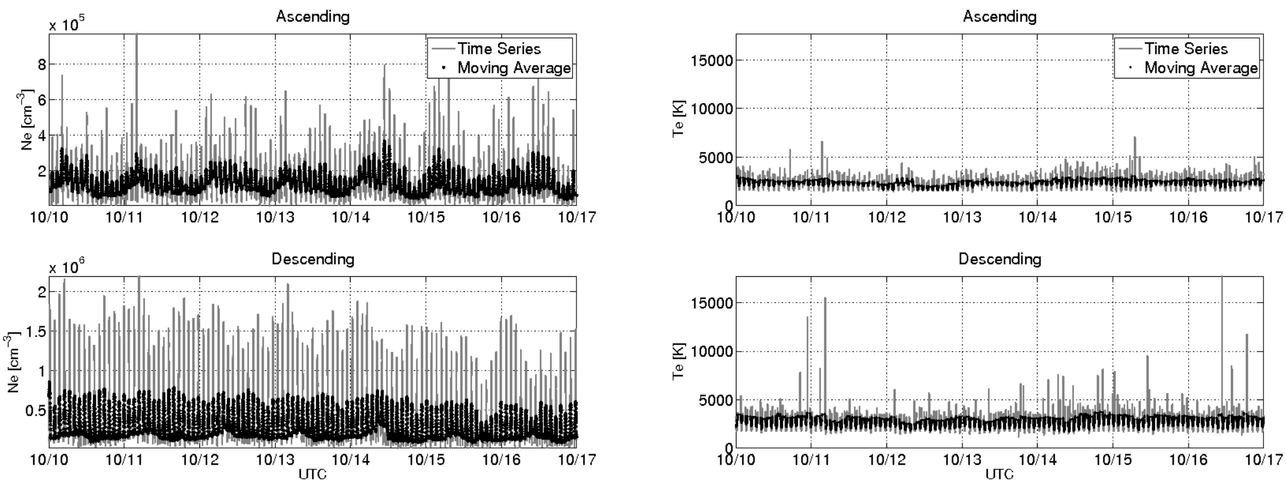

Figure 3-14: The panels show the electron density (left) and temperature (right) weekly time series (grey lines) together with the 20 min moving windows average (black lines). The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits. The average magnetic local time during the week is 12:30 p.m. for descending phase and 12:30 a.m. for ascending phase.

3.4.1.3 Swarm C

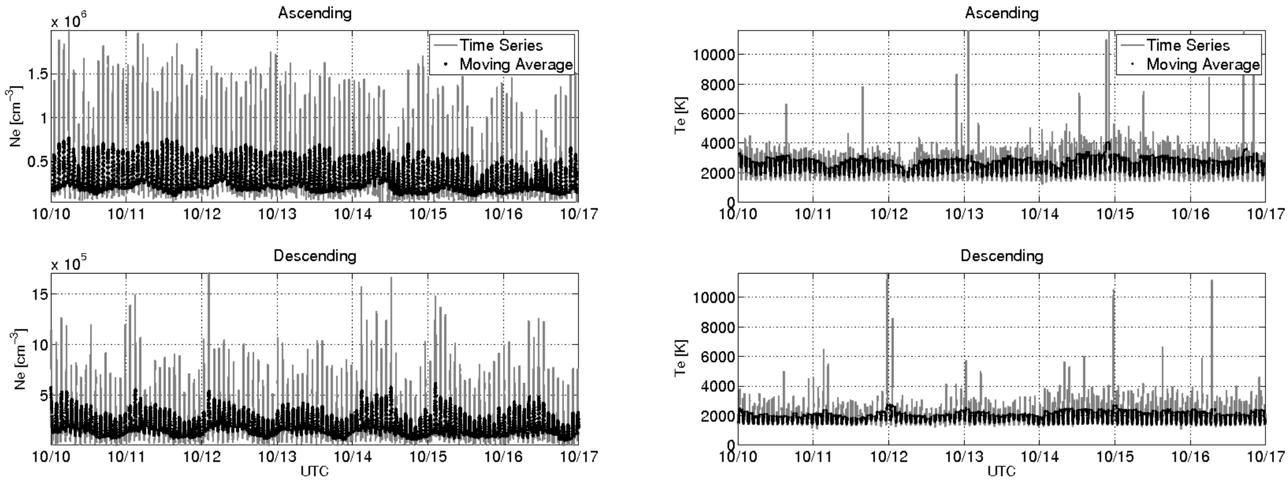

Figure 3-15: The panels show the electron density (left) and temperature (right) weekly time series (grey lines) together with the 20 min moving windows average (black lines). The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits. The average magnetic local time during the week is 11 a.m. for ascending phase and 11 p.m. for descending phase.

3.4.2 Plasma products latitudinal variations

3.4.2.1 Swarm A

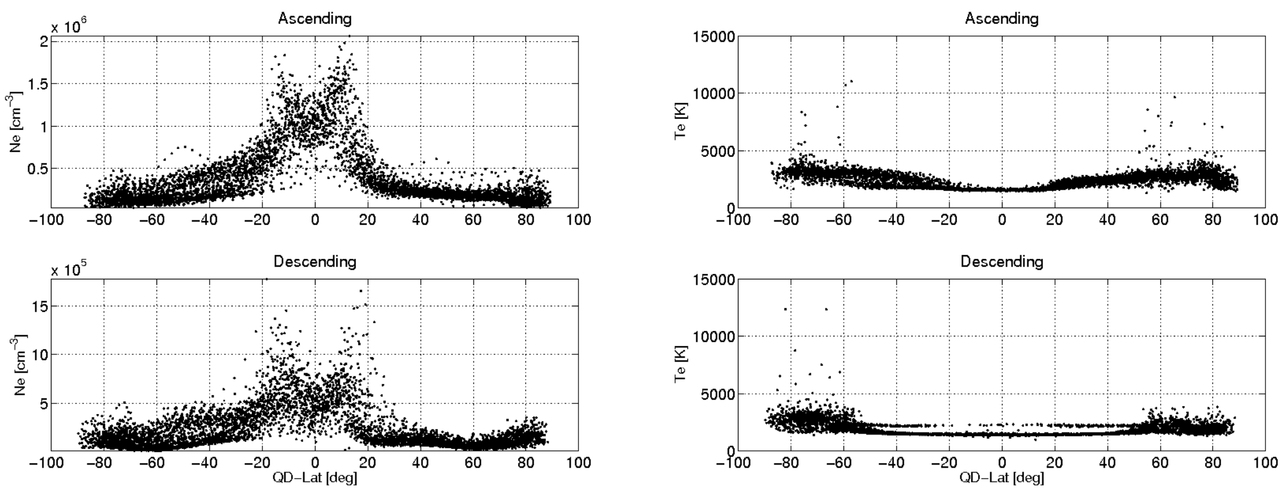

Figure 3-16: The panels shown the electron density (left) and temperature (right) profile as a function of QD Latitudes for the last week of operation. The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits.

3.4.2.2 Swarm B

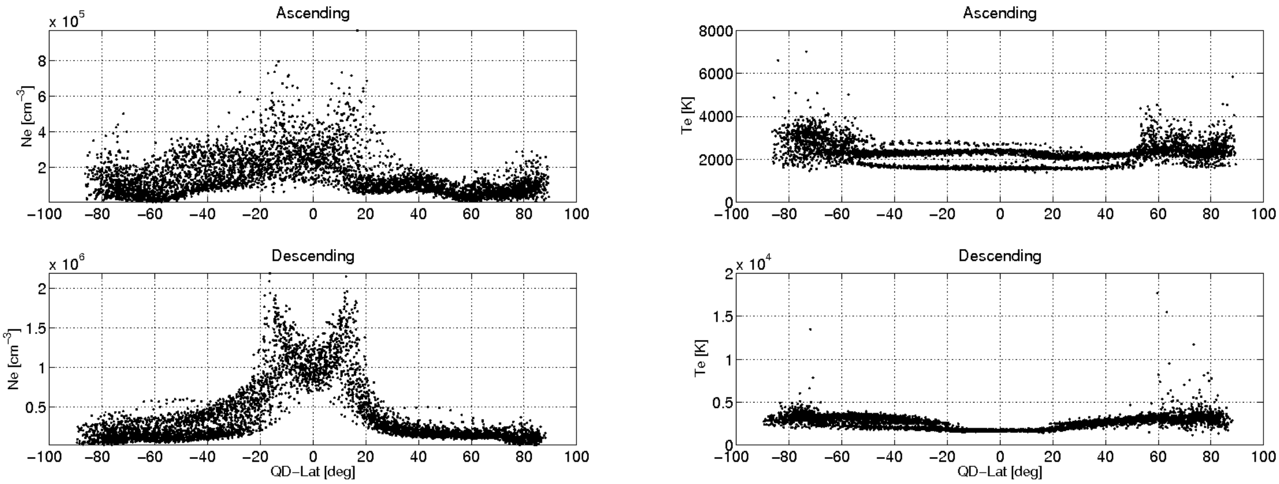

Figure 3-17: The panels shown the electron density (left) and temperature (right) profile as a function of QD Latitudes for the last week of operation. The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits.

3.4.2.3 Swarm C

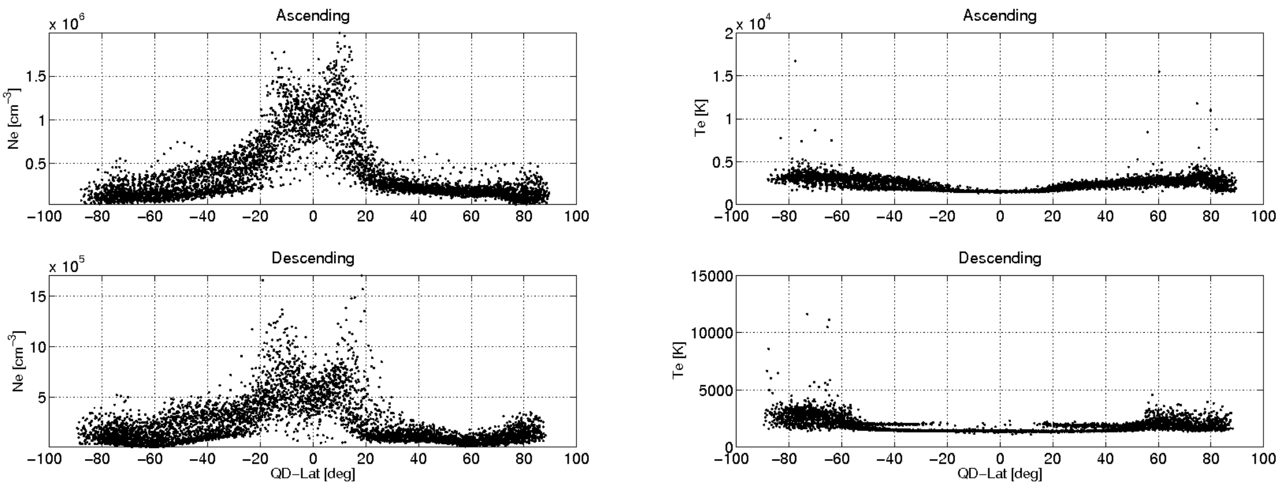

Figure 3-18: The panels shown the electron density (left) and temperature (right) profile as a function of QD Latitudes for the last week of operation. The analysis is made separately for ascending (upper panels) and descending (bottom panels) orbits.

4. Special Investigations

Nothing to report.

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