Monthly Report on MSS-1A Magnetic Data Quality for July 2026

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1 Introduction

1.1 About This Report

This report presents data-quality results based on MSS-1A Level-2 products reprocessed as Version 07 (V07), applied to observations from July 2026. The assessment covers: (1) detection of data anomalies; (2) evaluation of the vector fluxgate magnetometer (VFM) and the absolute scalar instrument (ASM — the Coupled Dark State Magnetometer, CDSM); and (3) consistency checks between observed and modeled geomagnetic fields.

The scope of this report includes data processing procedures, statistical analysis, and visual inspections of daily magnetic field variations. In addition, when comparing the observed magnetic field (in the NEC frame) with the CHAOS-8.6 internal field model [RD.02], the MMA (Magnetospheric Magnetic field) contribution is included [RD.03]; residuals are examined to provide a quantitative measure of calibration performance and model consistency.

Chapter 1 presents a general overview of the report and its main objectives. Chapter 2 focuses on in-orbit events and anomalies observed during satellite operation, such as changes in instrument temperature and disturbances and geomagnetic activity (e.g., magnetic storms). Chapter 3 provides a detailed assessment of the magnetic field data quality, including ΔF ($F_{ASM} - |\mathbf{B}_{VFM}|$) time series analysis, residual comparisons with the CHAOS-8.6 model, and visualization of these residuals. Chapter 4 summarizes the overall satellite data status for the month, highlighting any identified anomalies or quality issues.

1.2 Processor Evolution and Instrument Status

The VFM calibration processor was upgraded to version V07 and the entire Level-2 archive was reprocessed (V07) and released in October 2025. For example, an LR file name after the reprocessing looks like:

MSS1A_OPER_VFM_L2_MAG_SCI-LR_20231201T000000_20231201T235959_V0731.cdf

Details of dataset revisions and processor updates are documented in reference [RD.04]. The V07 L2-VFM and CDSM files for observations in July 2026 are the data object of this report and are publicly available from the MSS data portal (https://mss.must.edu.mo/data_download.html). In July 2026, the satellite's magnetic-field instruments showed nominal operation according to instrument flags.

1.3 Reference

[RD.01] Swarm DISC Weekly Report. https://earth.esa.int/eogateway/search?text=&category=Search%20all&instrument=magnetometers,asm,vfm&sortby=NEWEST_FIRST

[RD.02] Kloss, C.; Finlay, C.C.; Olsen, N.; Tøffner-Clausen, L.; Gillet, N.; Grayver, A. (2026) The CHAOS-8 geomagnetic field model, Earth Planets Space, DOI: 10.1186/s40623-025-02352-0.

[RD.03] Swarm Level 2 Processing System - Intermediate validation of Swarm Level 2 Magnetospheric Field Product. https://ftp.space.dtu.dk/data/magnetic-satellites/Swarm/SCARF/CI/Year3/MMA_VALi2C.pdf

[RD.04] MSS-1A VFM and CDSM Data Handbook. https://mss.must.edu.mo/image/handbook/MSS-1A%20VFM%20and%20CDSM%20Data%20Handbook-20251003.pdf

2 Event and Anomaly

2.1 Discrepancy of F between VFM and CDSM Data Files

In the published VFM and CDSM products, both files contain a scalar F. We denote the scalar from the CDSM file as F_{CDSM}, and the scalar from the VFM file as F_{VFM}. Their discrepancy is defined as $\delta F = F_{CDSM} - F_{VFM}$. No discrepancies exceeding the predefined threshold were identified in July 2026; therefore, no corresponding anomaly table is presented for this month.

We recommend users utilize the F variable from the VFM data files as the scalar measurement value of the MSS-1A satellite, rather than that from the CDSM data files, because the former is used in the in-flight calibration.

2.2 VFM Temperature Monitoring

Figure 2-1 shows the temperature variations for CDC, CSC, and EU during July 2026. The temperature variations remained within the normal range for the month. The maximum temperature observed for CDC was 2.87°C, for CSC 0.09°C, and for EU 28.21°C. The average temperatures were 2.00°C for CDC, -1.26°C for CSC, and 26.67°C for EU. The Huber-weighted RMS values were 0.49°C for CDC, 0.78°C for CSC, and 0.56°C for EU. Here we focus on temperature variability because short-term fluctuations can affect magnetometer calibration and instrument performance.

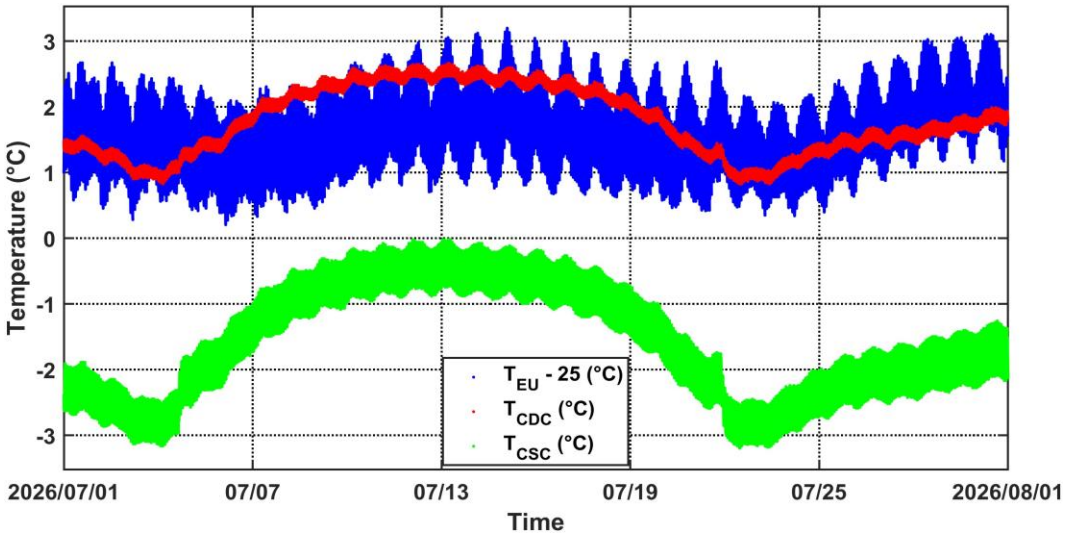


Figure 2-1: Temperature variations of CDC, CSC, and EU during July 2026. The temperature of EU is adjusted by subtracting 25°C.

2.3 Inter-boresight check

The attitude stability of the optical platform from November 2023 to July 2026 is evaluated by monitoring inter-boresight angles (IBAs). Figure 2-2 shows the three camera-pair IBAs (CHUA–CHUB, CHUA–CHUC, CHUB–CHUC, CHU = Camera Head Unit) for the period November 2023 to July 2026. The panels present time series of IBAs after mean removal; the legend of each panel reports the sample mean and the Huber-weighted RMS. Figure 2-3 shows the residual IBAs between the combined quaternion (the L2 VFM product q_NEC_CRF) and the quaternions from individual cameras. These residuals evaluate the improvement in both reliability and accuracy achieved by the combination algorithm relative to single-camera attitude determination. All time series were plotted using 60-s sampling for display clarity.

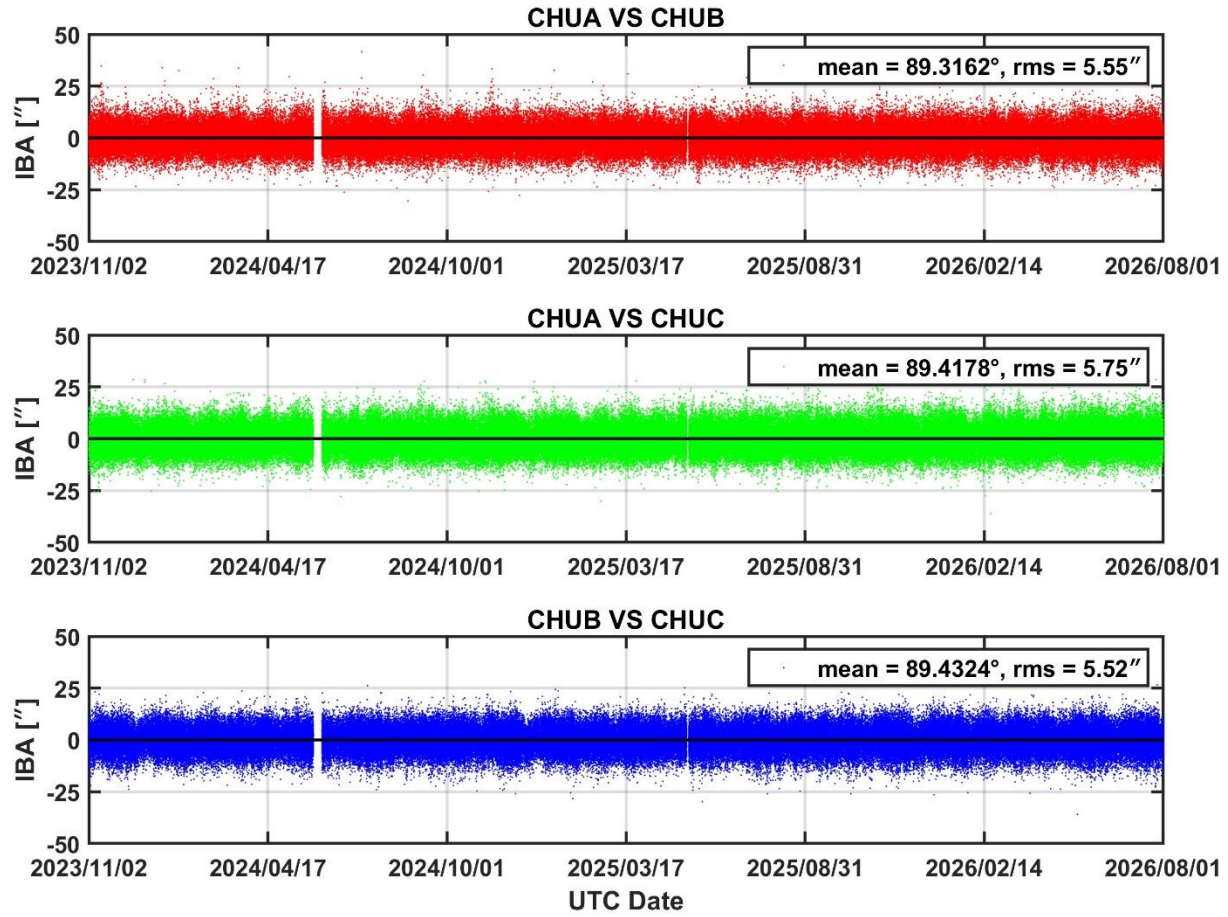


Figure 2-2: Time series of inter-boresight angles (IBA) between the three star-tracker Camera Head Units (CHU): CHUA–CHUB, CHUA–CHUC, and CHUB–CHUC. Values are per-series mean removed and shown in arc-sec. Sampling for plotting: 60 s.

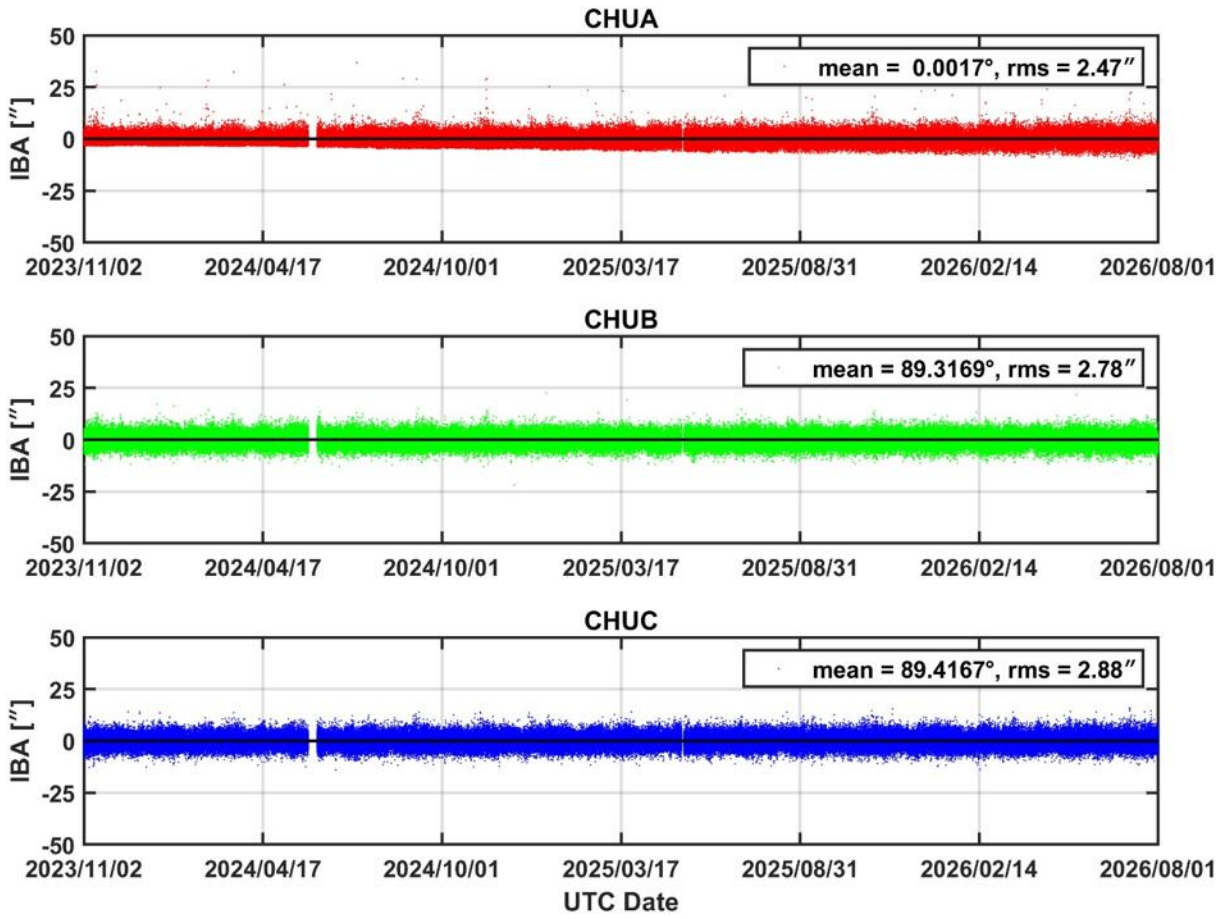


Figure 2-3: Residual IBA time series between the combined quaternion (q_NEC_CRF, L2 VFM) and each single-camera quaternion (units: arc-sec). Small residuals (≲10 arc-sec) indicate good platform stability and effective attitude combination.

Physically, small IBA fluctuations reflect the mechanical/thermal stability of the optical bench and the internal consistency of the quaternion-combination strategy. If residuals between the combined quaternion and the single-camera quaternions remain within ±10 arc-sec, the platform stability and the combination algorithm can be regarded as sufficient for VFM alignment requirements. In our re-analysis for November 2023 to July 2026, the combined-vs-single-camera residuals are largely confined within ± 10 arc-sec, indicating stable platform performance and satisfactory behavior of the attitude-combination method.

2.4 Geomagnetic Activity

Figure 2-4 illustrates the temporal evolution of geomagnetic activity during July 2026, as captured by the Kp index (black line, left axis) and the RC index (blue dashed line, right axis). A significant magnetic

storm occurred around July 04, where the Kp index peaked above 7.3. The RC index reached values as low as -157 nT.

The Kp index can be downloaded from https://kp.gfz-potsdam.de/en/data, and the RC index from http://www.spacecenter.dk/files/magnetic-models/RC/current/.

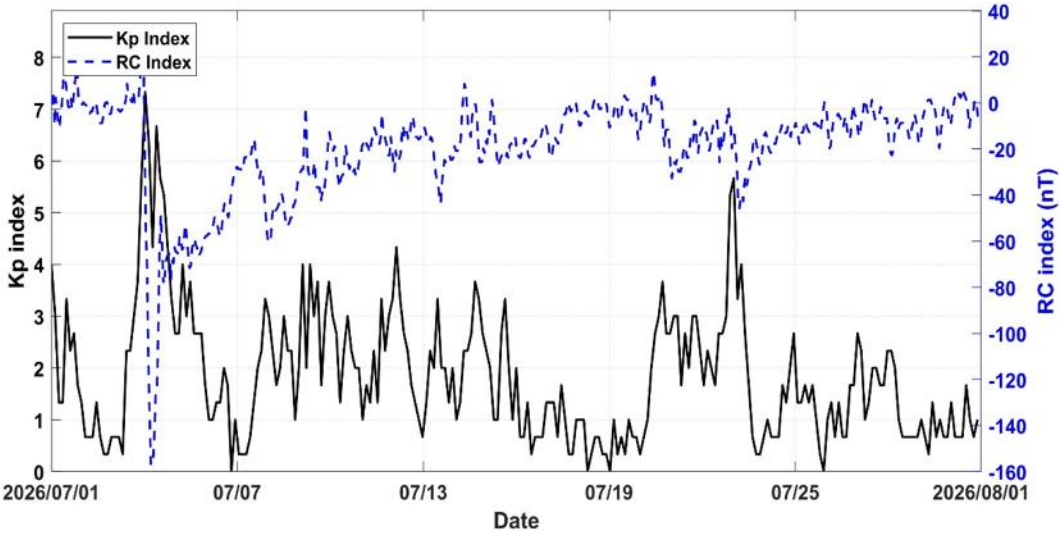


Figure 2-4: Kp (black) and RC (blue) indices showing geomagnetic activity during July 2026.

3 Magnetic Products

This chapter focuses on the quality inspection of the officially released Level 2 scalar (CDSM) and vector (VFM) magnetic field products from the MSS-1A satellite. The analyses aim to assess the temporal stability, detect anomalies, and ensure the reliability of the magnetic measurements. The monitoring includes the following key aspects:

- **Data Range Check:** The magnetic field values of the Level-2 products are systematically checked to ensure they fall within the expected physical range (±18,000 to ±60,000 nT). In addition, the satellite's orbit is verified to remain within the expected spatial coverage (latitude ⩽ 41°, altitude between 415–495 km). To help identify unusual events or anomalous behavior, additional statistics of the Flag_B quality indicator are compiled for further analysis.
- **ΔF Time Series Inspection**: Daily time series of the residuals $\Delta F = F_{ASM} - |\mathbf{B}_{VFM}|$ are visually inspected to monitor the differences between the ASM and VFM. For each day, the mean variation and standard deviation of ΔF are recorded. An alert is raised if the daily mean or RMS of ΔF exceeds ±1 nT. A time series of the RMS of ΔF is then generated.
- **ΔF Statistical Summary**: Mean and standard deviations of ΔF are analyzed over both the current month and the entire available period (since November 2023), providing an overview of the long-term performance of the instruments and highlighting temporal or spatial anomalies.
- **Magnetic Component Inspection**: Daily and monthly variations of the magnetic intensity F and the three $\mathbf{B}_{NEC}$ components are visualized to identify potential jumps, gaps, or systematic errors.
- **Model Residual Analysis**: The observed $\mathbf{B}_{NEC}$ field is compared with the CHAOS-8.6 model, and residual maps are computed and plotted to reveal geophysical signals or potential instrument deviations.

3.1 Out-of-threshold Values

(1) Values exceeding ±60,000 nT or smaller than ±18,000 nT: No out-of-threshold values were detected in the NEC vector components, in the scalar field F derived from CDSM, or in field intensity calculated from $\mathbf{B}_{VFM}$ within the Level-2 data for July 2026.

(2) All recorded values fall within the normal operating bounds:

- |latitude| ⩽ 41°
- 415 km ⩽ height ⩽ 495 km

No positional anomalies were detected this month, indicating nominal satellite orbit and data acquisition.

(3) The Flag_B indicator is used to assess the quality of the magnetic field measurements on board MSS-1A. Each Flag_B value denotes a specific anomaly or condition observed during data acquisition. The flags are defined as follows:

- 0: nominal;
- 1: data is derived through interpolation;
- 2: outliers when $|F_{ASM} - |\mathbf{B}_{VFM}|| > 1$ nT;
- 3: interpolated data points with $|F_{ASM} - |\mathbf{B}_{VFM}|| > 1$ nT;
- 4: position fault when h < 415 km or h > 495 km or abs(latitude) > 41°, where h is satellite height.

For each day in July 2026, the number of observations corresponding to each Flag_B level was counted (expected 86,400 samples/day at 1-Hz); results are summarized in Table 3-1.

Table 3-1: Summary of Flag_B Statistics for July 2026

DATE	num_FlagB_eq0	num_FlagB_eq1	num_FlagB_eq2	num_FlagB_eq3	num_FlagB_eq4
20260701	86346	0	54	0	0
20260702	86394	0	6	0	0
20260703	86339	0	61	0	0
20260704	86379	0	21	0	0
20260705	86017	0	383	0	0
20260706	86238	0	162	0	0
20260707	86196	0	204	0	0
20260708	86150	0	250	0	0
20260709	86053	0	347	0	0
20260710	85896	0	504	0	0
20260711	86025	0	375	0	0
20260712	86063	0	337	0	0
20260713	86079	2	319	0	0
20260714	86113	0	287	0	0
20260715	85829	9	543	19	0
20260716	85790	0	610	0	0
20260717	85677	0	723	0	0
20260718	86058	0	342	0	0
20260719	86006	0	394	0	0

20260720	86094	2	304	0	0
20260721	85871	2	527	0	0
20260722	86194	2	204	0	0
20260723	86369	2	29	0	0
20260724	86381	0	19	0	0
20260725	86197	0	203	0	0
20260726	85927	0	473	0	0
20260727	85496	0	904	0	0
20260728	84914	0	1486	0	0
20260729	85516	2	882	0	0
20260730	85637	0	763	0	0
20260731	85336	0	1064	0	0

DATE indicates the observation date in the format yyyymmdd. num_FlagB_eq0 represents the total number of records with Flag_B = 0, indicating nominal measurements. Other columns follow the same convention, referring to different Flag_B levels.

3.2 ASM – VFM Anomaly

To validate the physical consistency between vector and scalar magnetic measurements, we define the residual ΔF as the difference between the scalar measurement F_{ASM} and the magnitude of the VFM vector field $|\mathbf{B}_{VFM}|$, such that $\Delta F = F_{ASM} - |\mathbf{B}_{VFM}|$.

It is worth noting that we use δF to denote the difference in the scalar field F between the L2 CDSM file and the L2 VFM file, while ΔF is used to represent the difference between the scalar field F and the vector field strength $|\mathbf{B}|$ in the L2 VFM file.

Under ideal calibration conditions, ΔF should remain close to zero, indicating that the vector magnetometer's sensitivities (scale factors), offsets and non-orthogonalities have been properly corrected. Systematic or large residuals may reflect issues in vector calibration, external disturbances—such as sunlight-induced perturbations, or instrumental failures.

Figure 3-1 shows the temporal evolution of ΔF throughout July 2026 using unscreened VFM and CDSM data, displaying the original range of variation without applying any filtering to the data. Most values fluctuate within ± 1 nT, but occasional spikes appear, indicating short-term disturbances or outliers in the measurements. Overall, the data distribution is centered around zero, suggesting that the instrument calibration is generally stable.

To monitor calibration performance and detect possible anomalies, four key statistics are computed daily throughout the month:

- The minimum and maximum values of ΔF, indicating the range of deviations;
- The mean and root-mean-square (RMS) values of ΔF, quantifying the average daily bias and variability.

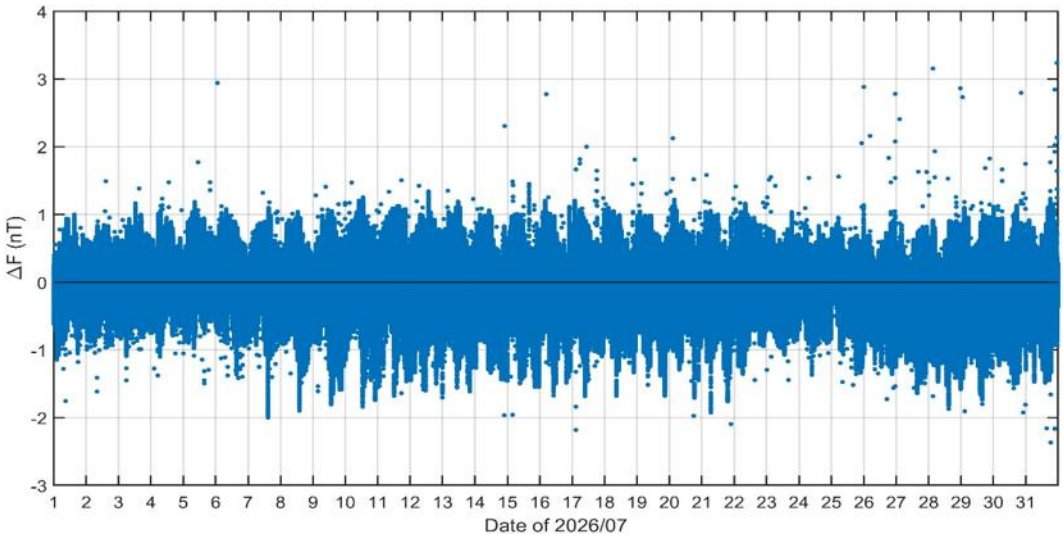


Figure 3-1: Temporal variation of ΔF calculated from unscreened VFM and CDSM data in July 2026.

The table below presents the daily statistical summary of scalar magnetic residuals for July 2026, displaying the daily minimum, maximum, mean, and Huber-weighted RMS values of ΔF. The last row of the table provides a summary of the overall statistics for the entire month. All statistics were computed after applying a uniform data screening, retaining only samples with F and $|\mathbf{B}_{VFM}|$<52,000 nT and |ΔF| ⩽ 20 nT; the same criteria are used throughout the subsequent ΔF analyses.

Table 3-2: Daily statistics of ΔF for July 2026 (Unit: nT)

Date	20260701	20260702	20260703	20260704	20260705	20260706	20260707	20260708
Min	-1.754	-1.617	-1.450	-1.376	-1.494	-1.417	-1.999	-1.897
Max	0.999	1.490	1.381	1.476	1.769	2.941	1.320	1.038
Mean	-0.024	-0.008	0.024	0.020	0.087	0.024	-0.000	-0.005
RMS	0.267	0.261	0.274	0.260	0.272	0.290	0.255	0.251
Date	**20260709**	**20260710**	**20260711**	**20260712**	**20260713**	**20260714**	**20260715**	**20260716**
Min	-1.807	-1.838	-1.677	-1.704	-1.613	-1.962	-1.960	-1.675
Max	1.409	1.471	1.504	1.420	1.347	2.305	1.485	2.774
Mean	0.012	-0.013	-0.008	-0.008	0.026	-0.000	-0.026	-0.017
RMS	0.254	0.241	0.237	0.245	0.251	0.241	0.252	0.266
Date	**20260717**	**20260718**	**20260719**	**20260720**	**20260721**	**20260722**	**20260723**	**20260724**
Min	-2.181	-1.680	-1.677	-1.973	-2.093	-1.446	-1.446	-1.367
Max	2.001	1.809	1.460	2.126	1.580	1.412	1.552	1.539

Mean	0.008	0.011	0.026	0.005	-0.044	0.008	-0.061	-0.089
RMS	0.277	0.269	0.252	0.272	0.296	0.273	0.287	0.251
Date	**20260725**	**20260726**	**20260727**	**20260728**	**20260729**	**20260730**	**20260731**	**202607**
Min	-1.516	-1.725	-1.641	-1.872	-1.905	-1.925	-2.365	-2.365
Max	2.880	2.781	2.406	3.156	2.733	2.795	3.236	3.236
Mean	-0.066	-0.104	-0.119	-0.106	-0.093	-0.087	-0.080	-0.023
RMS	0.270	0.253	0.253	0.288	0.311	0.311	0.297	0.268

Violation of ΔF threshold:

- Mean residuals (absolute value>1 nT): no violations.
- RMS residuals (>1 nT): no violations.

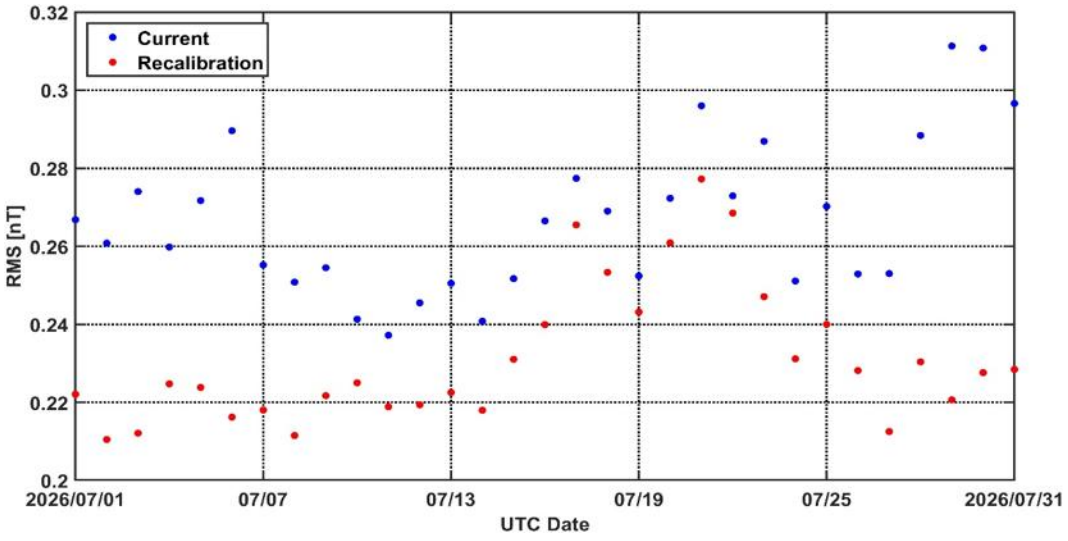


Figure 3-2: ΔF RMS statistics of MSS-1A Level 2 data (blue) and daily in-flight recalibration results (red) for July 2026.

Figure 3-2 presents the Huber-weighted root-mean-square (RMS) of ΔF for MSS-1A Level 2 VFM data in July 2026 (blue dots). The daily in-flight recalibration results (red dots) show reduced RMS values compared with the baseline processing. This improvement is more likely attributable to imperfect original calibration parameters; daily recalibration reduces calibration-related residuals.

For overall data calibration (blue dots), a quality filter was applied to remove physically unreasonable data points. This ensured that outliers would not bias the calibration results. The same screening criteria were also applied in the daily nine-parameter recalibration. In addition, the use of the Huber weighting scheme further improves robustness by down-weighting residuals from outlier points during RMS computation.

Figure 3-3 displays the temporal variation of ΔF RMS values in VFM files since November 2, 2023. Overall, the RMS variation of MSS-1A data remains stable.

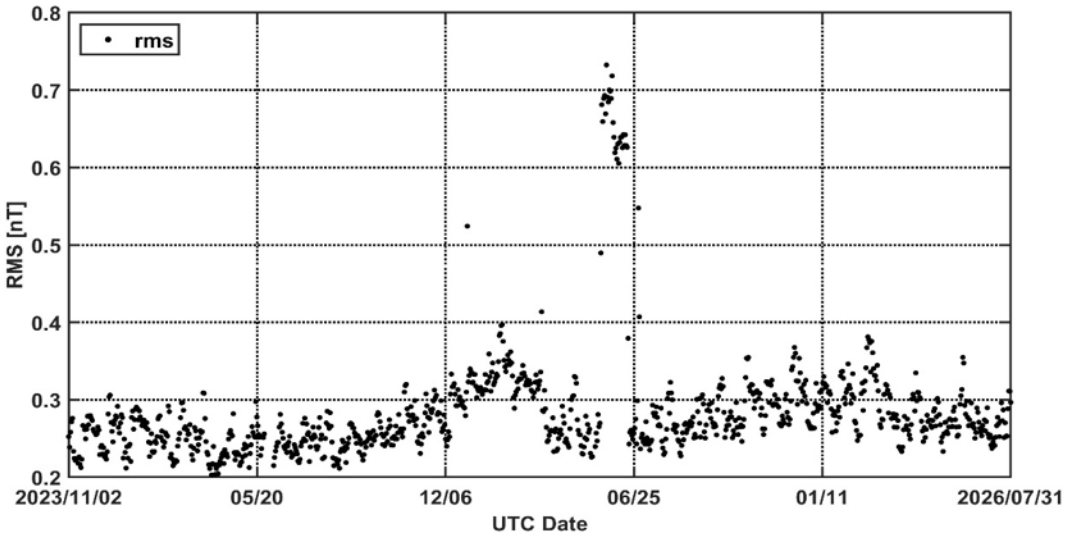


Figure 3-3: Temporal evolution of ΔF RMS values in VFM data from November 2023 to July 2026.

3.3 ASM – VFM Difference Statistics

Figure 3-4 shows the daily mean (circles) and standard deviation (crosses) of ΔF of July 2026. Figure 3-5 extends this analysis by presenting the daily mean and standard deviation values of ΔF from November 2023 to July 2026. The subsequent two plots (Figures 3-6 and 3-7) present ΔF analyses for July 2026. Figure 3-6 shows the time series for the month, with daytime and nighttime measurements represented by red and blue dots, respectively. The residuals primarily remain within ±2 nT, though occasional outliers are present. Statistical metrics displayed in the top-left corner indicate consistent mean and RMS values for both daytime and nighttime ΔF throughout the month. Figure 3-7 illustrates the spatial distribution of ΔF across longitude and latitude coordinates.

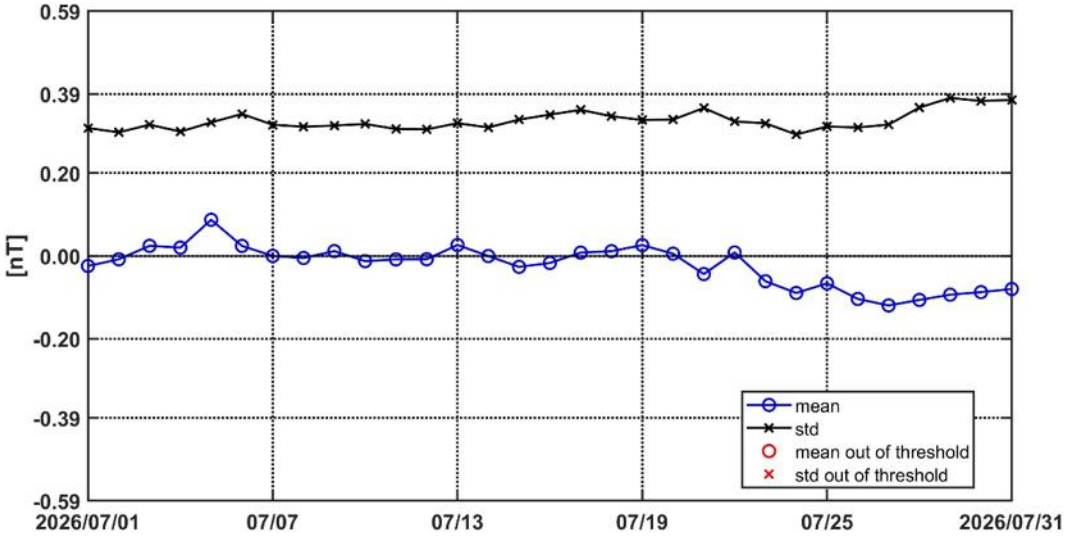


Figure 3-4: Daily mean and standard deviation values of ΔF in July 2026. Red circles and crosses indicate days where the absolute values of the mean and root-mean-square (RMS) residuals exceed 1 nT. (This situation does not occur during this month). The standard deviation shown is computed as the sample standard deviation (divided by n–1).

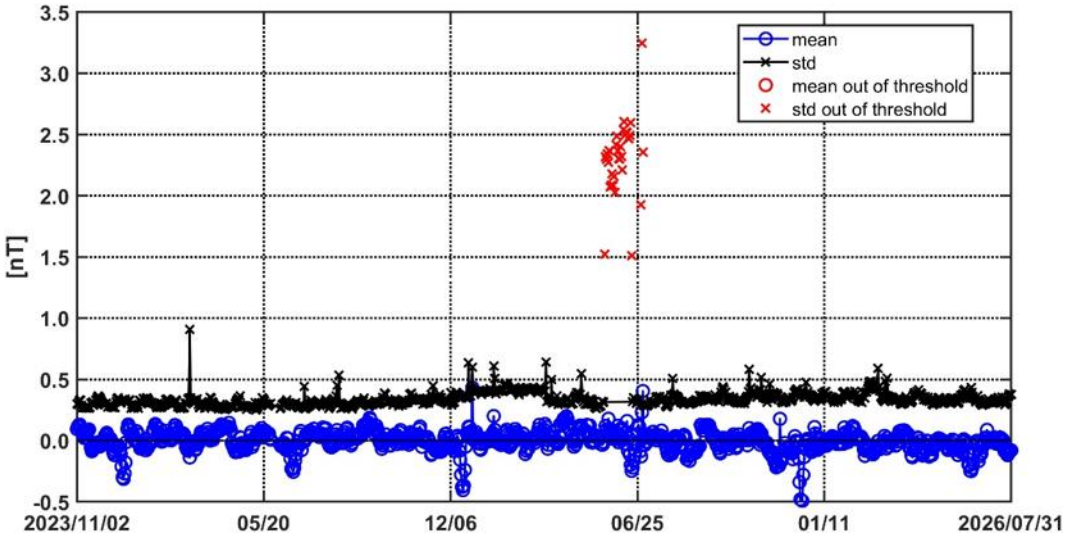


Figure 3-5: Daily mean and standard deviation values of ΔF from November 2023 up to July 2026.

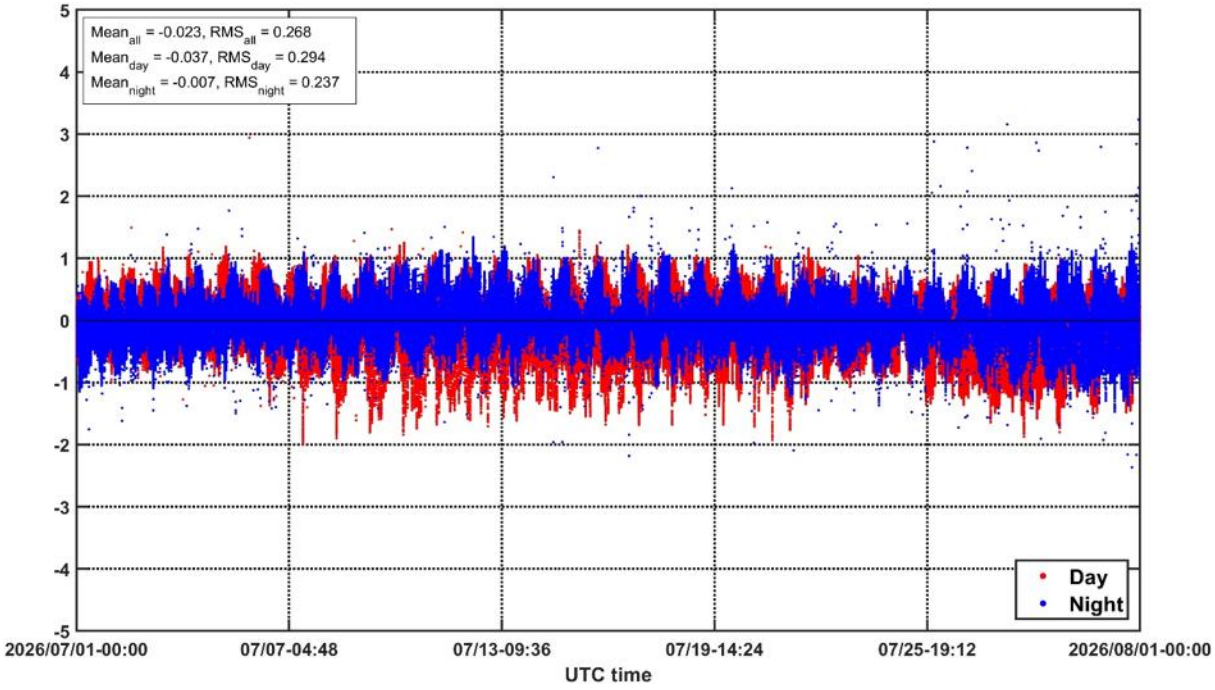


Figure 3-6: ΔF time series during July 2026 (unit: nT). Red and blue dots represent daytime and nighttime measurements, respectively.

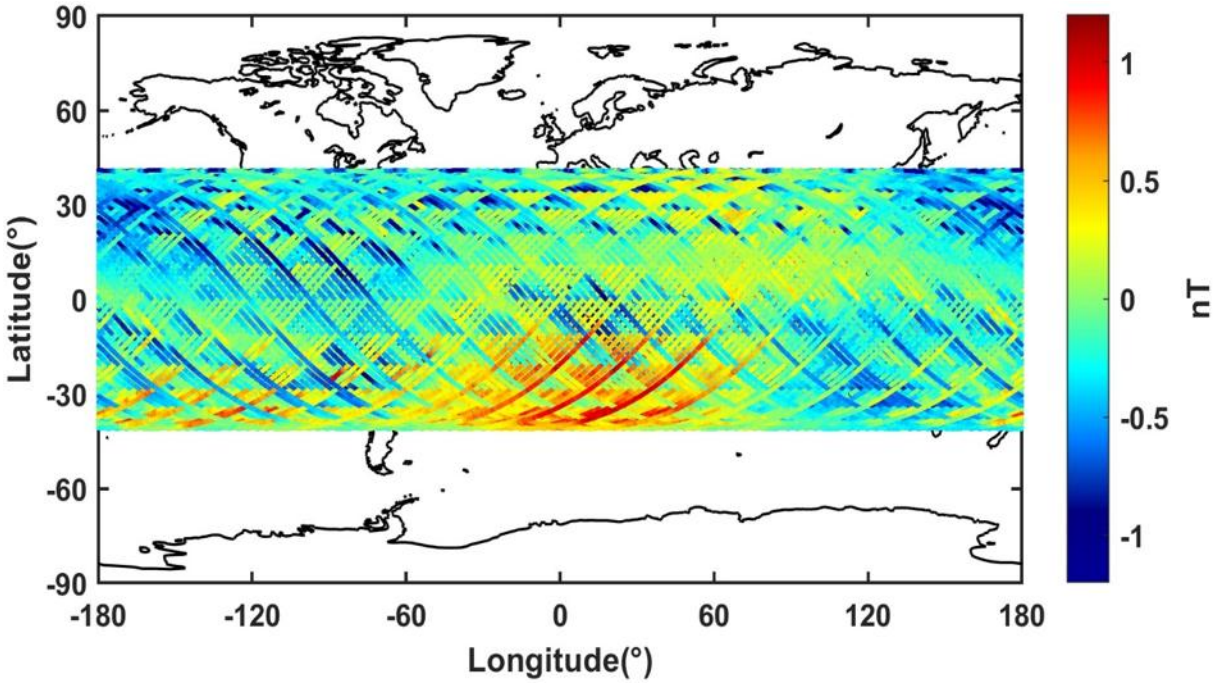


Figure 3-7: Residuals ΔF for July 2026 are plotted on the world map.

3.4 Magnetic Components Visual Inspection

Below are four sub-figures showing global maps of variables F_{ASM} and $\mathbf{B}_{NEC}$ for July 2026. The scalar field F_{ASM} is derived from ASM measurements, and the $\mathbf{B}_{NEC}$ components are obtained from VFM measurements in the NEC frame. Visual inspection confirms that the measured magnetic field is broadly consistent with current geomagnetic model outputs and reveals no large-scale artifacts in the data.

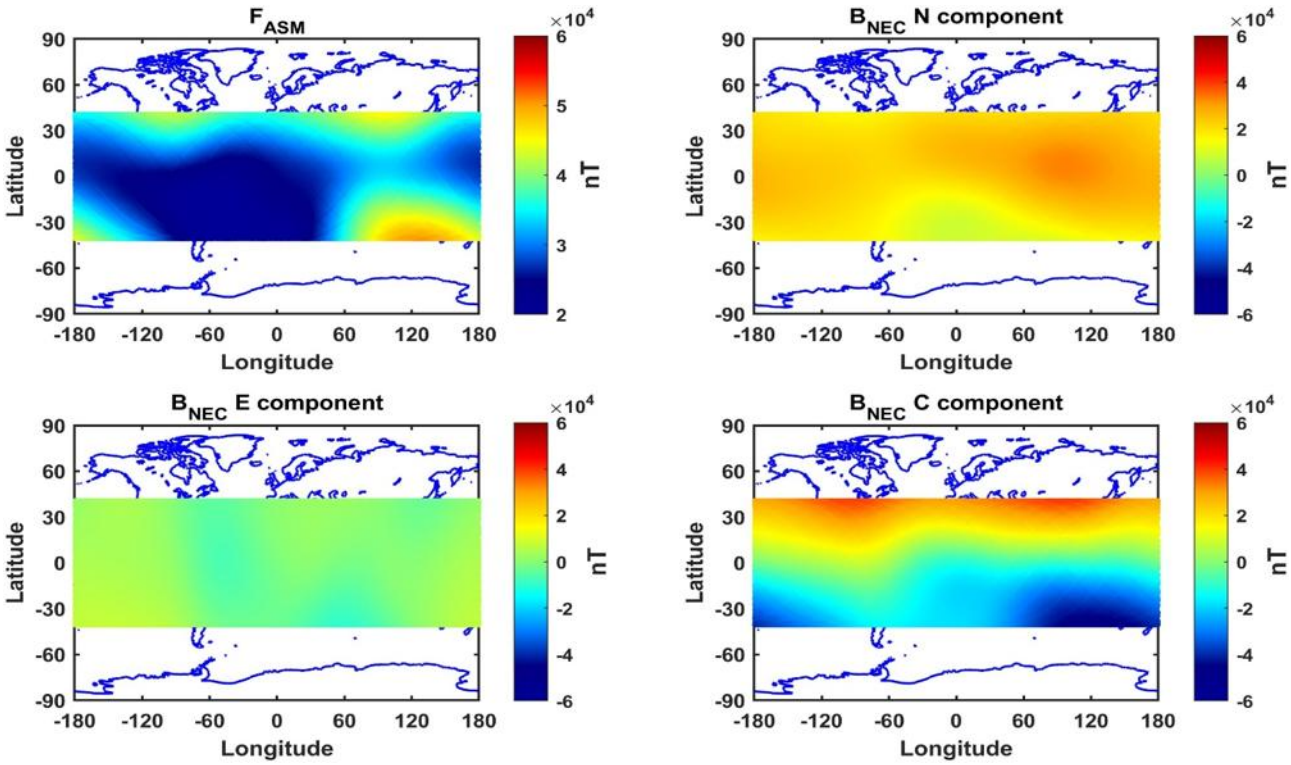


Figure 3-8: World map plots of the geomagnetic field and components for July 2026. From top to bottom: F_{ASM} from ASM measurement, and B_N, B_E, B_C components in the NEC frame from VFM measurement.

3.5 B_{NEC} – CHAOS-8.6 Model Residuals

Figures 3-9 and 3-10 show the differences between MSS-1A magnetic field measurements and the CHAOS-8.6 model in July 2026. The model includes the main (core) field, the lithospheric (crustal) field up to spherical-harmonic degree 60, and magnetospheric (and induced) contributions.

For time intervals where CHAOS does not provide up-to-date external-field (magnetospheric /induced) estimates, we compute those external contributions using the MMA model.

Figure 3-9 displays the residuals $\Delta B = \mathbf{B}_{NEC} - \mathbf{B}_{CHAOS}$ as a function of colatitude, while Figure 3-10 presents the same residuals as a function of UTC time. From top to bottom, the panels show the northward (ΔB_N), eastward (ΔB_E), downward (ΔB_C), and scalar (ΔF_{CHAOS}) residuals. Here and throughout this section, ΔF_{CHAOS} denotes the scalar difference between the measured F_{ASM} and the CHAOS-8.6 model value. In July 2026, the residuals remained generally stable at low and mid latitudes (|latitude| $\leqslant$ 41°), with extreme values reaching -142.36 nT, -110.42 nT, 49.14 nT, and -106.16 nT for ΔB_N, ΔB_E, ΔB_C and ΔF_{CHAOS}, respectively.

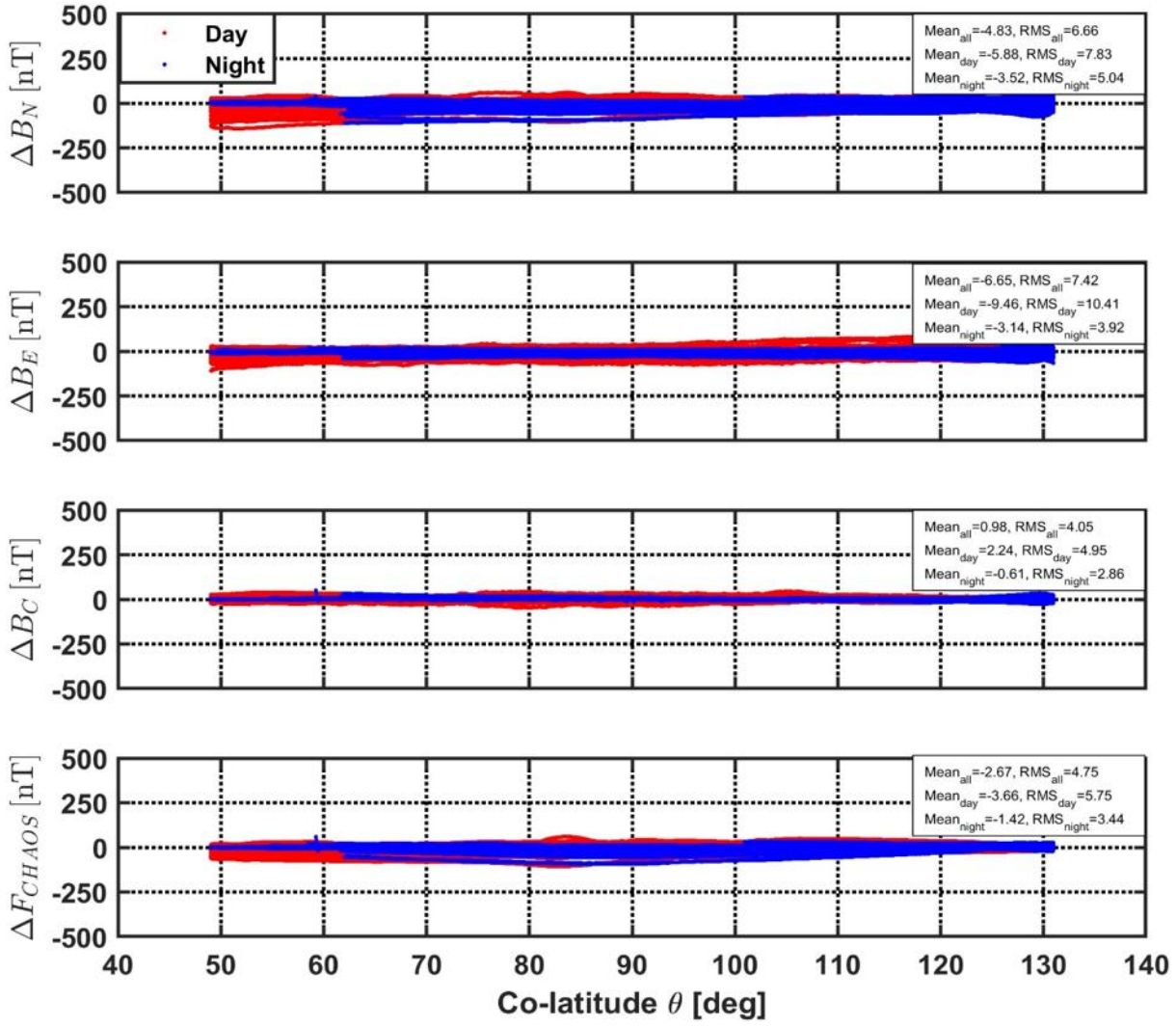


Figure 3-9: Differences between measurements and the CHAOS-8.6 model along the colatitude. From top to bottom: differences of northward, eastward, downward and scalar components.

Figure 3-9 illustrates residual amplitudes that remain stable under predominantly quiet geomagnetic conditions. No significant storm-related enhancements are observed during this month, and similar behavior is evident in Swarm data.

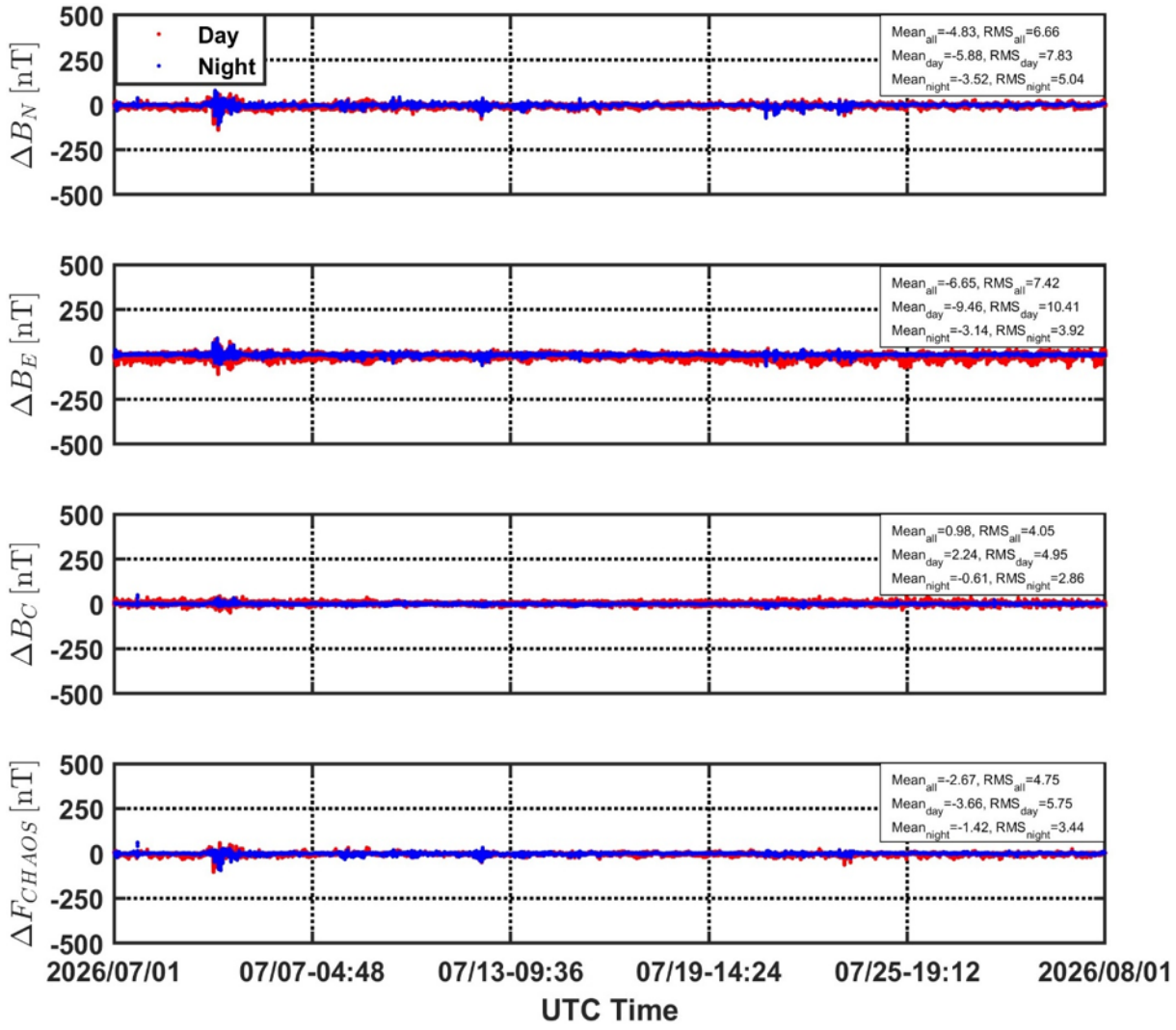


Figure 3-10: Differences between measurements and the CHAOS-8.6 model along the UTC time. From top to bottom: differences of northward, eastward, downward and scalar components.

Figure 3-10 presents the residual time series between the MSS-1 magnetic-field measurements and the CHAOS-8.6 model for July 2026. The residuals exhibit overall stable behavior under predominantly quiet geomagnetic conditions, consistent with Swarm observations at low and mid latitudes.

4 Summary

This report provides a comprehensive assessment of the MSS-1A satellite magnetic field data quality during July 2026. The main findings are as follows:

- **Data Integrity:**
  No physically unrealistic values were found in the $\mathbf{B}_{\mathrm{NEC}}$, $\mathbf{B}_{\mathrm{VFM}}$, or scalar (F) components of the Level-2 data. No out-of-threshold in VFM products were observed this month. Scalar–vector differences remained consistently within acceptable bounds.

- **Satellite Position Check:**
  Satellite altitude and latitude were checked against thresholds of 415–495 km and |latitude| $\leqslant$ 41°. No positional anomalies were detected in July 2026, and the data can be used with confidence.

- **Instrument Performance:**
  The VFM and ASM instruments operated normally throughout the month. Temperature readings from CDC, CSC, and EU remained stable. The upgraded Level-2 data processor (Version 07) functioned as expected, and the dataset showed no signs of data loss or systematic drift.

- **Calibration and Model Residuals:**
  Overall, daily mean and Huber-weighted RMS values of ΔF were generally within ± 1 nT during July 2026, and no values exceeded 10 nT. Daily in-flight recalibration using LR data further reduced ΔF scatter. Comparisons with the CHAOS-8.6 model also confirmed that residuals in the NEC frame were well within expected bounds.

In conclusion, the MSS-1A magnetic field data for July 2026 is complete and of high quality.