Local time asymmetry of the Earth's ring currents derived from Swarm satellite magnetic data

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Abstract

The azimuthal morphology of the Earth's ring currents was reported always asymmetric during extreme space weather events at low latitudes, such as geomagnetic storms. A dawn-dusk pattern was detected during the storm main phase with near-Earth and in-situ magnetic measurements. Recently evidences were confirmed that asymmetric ring currents exist in quiet times and storm recovery phase. In this study, the local time asymmetry of the ring current is estimated by low-Earth-Orbit Swarm data. Spherical harmonics models are developed to quantify the energy of ring currents by external Gauss coefficients during both quiet periods and storm recovery phase.

Introduction

The asymmetric azimuthal morphology of Earth's ring currents is an important issue to understand the status of inner magnetospheric dynamics during various geomagnetic disturbed levels. It generates non-uniform distribution of southward magnetic fields at mid-low latitudes near the Earth's surface, which was observed always strongly perturbed at the dusk-midnight sector during storm times by ground-based observatories, and by near-Earth satellite magnetic measurements (e.g. Le et al., 2011).

The dawn-dusk asymmetry of the ring current was generally associated with the existence of the partial ring current at least in the main phase and early recovery phase (see the review by Walsh et al., 2014 and reference therein).

Open discussions on the ring current asymmetry in quiet times and in the storm recovery phase were also raised by various authors. Most of previous studies exhibit more symmetric current feature in the late recovery phase, compared to that in the main phase (e.g. see the review of Daglis, 2006 and reference therein).

Data and method

The rate of local time change for Swarm satellite Alpha (Sat_A) and Bravo (Sat_B) is ~2.7 hrs/month and ~2.6 hrs/month, respectively. The orbital plane of Sat_B relative to Sat_A drifts at the rate of ~2º/month (Figure 1a). In a short time period, for example 10 days, each satellite stays in a relative stable local time sector with change less than 1 hour (Figure 1b, 1c)

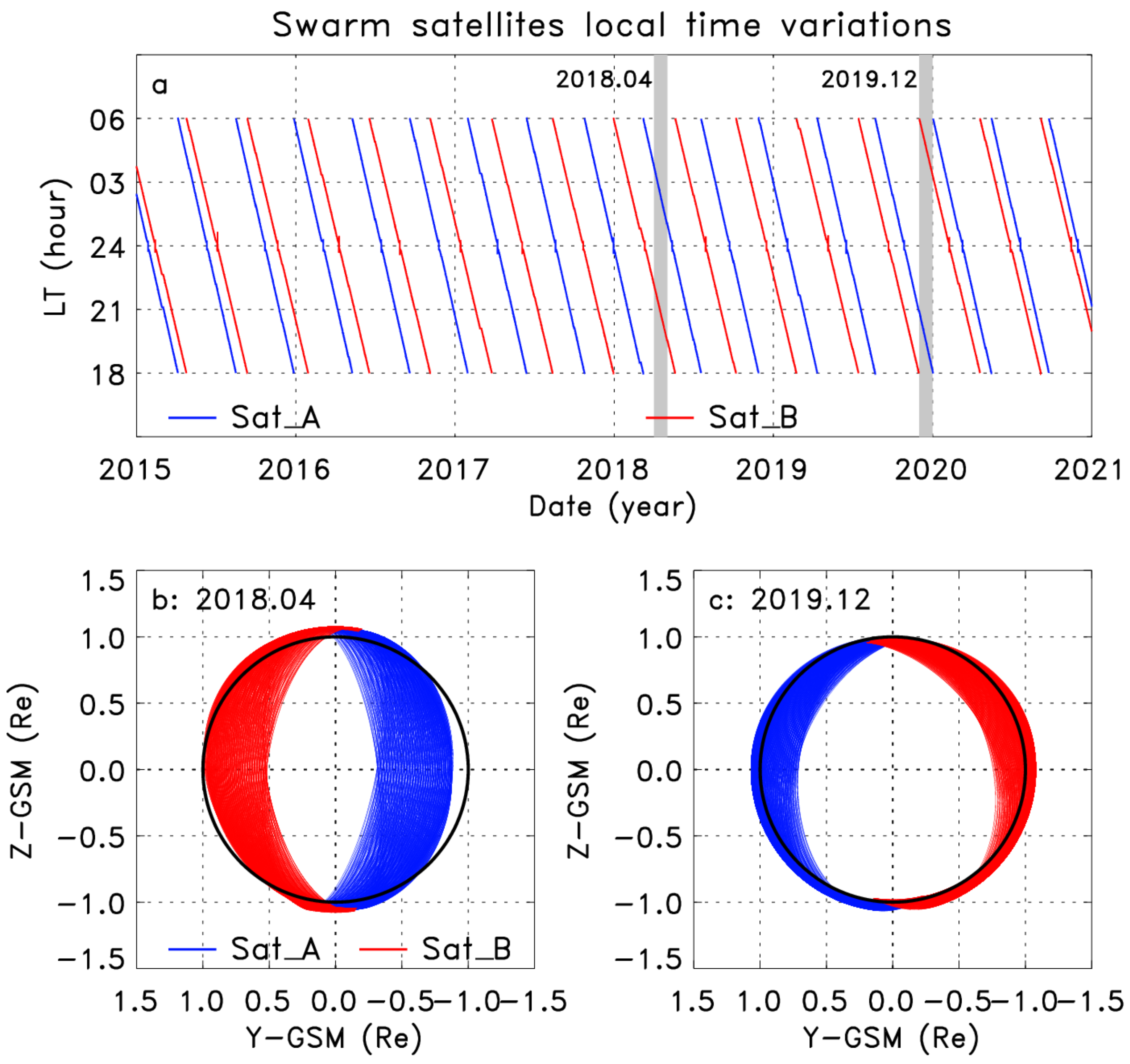


Figure 1 (a) The rate of local time change for Swarm Sat_A and Sat_B. (b), (c) The orbit distribution of Sat_A and Sat_B in April 2018 and December 2019 in the GSM Y-Z plane, respectively.

In this study, global spherical harmonics models are built according to the method provided by Olsen (2002), but with simpler spherical harmonics expressions. The magnetic field derived from a magnetic scalar potential *V* can be expanded in terms of SH expressions. The truncation level is set for the internal fields and for the external fields.

Results

Swarm vector (|Lat| < 55º) and scalar (|Lat| > 55º) magnetic data are used to inverse the Gauss coefficients in a short time section that less than 10 days. According to the geomagnetic activity level, three data selections are adopted. (a) The data with Sym-H ∈ [0, 10] nT; (b) The data with Sym-H ∈ [-10, 0] nT; (c) The data in the storm recovery phase. Figure 2 shows the data residuals of SHA model in Group (a) with respect to geomagnetic colatitude. From top to bottom are the residual of Bx, By, Bz, and Bf components in NEC coordinates.

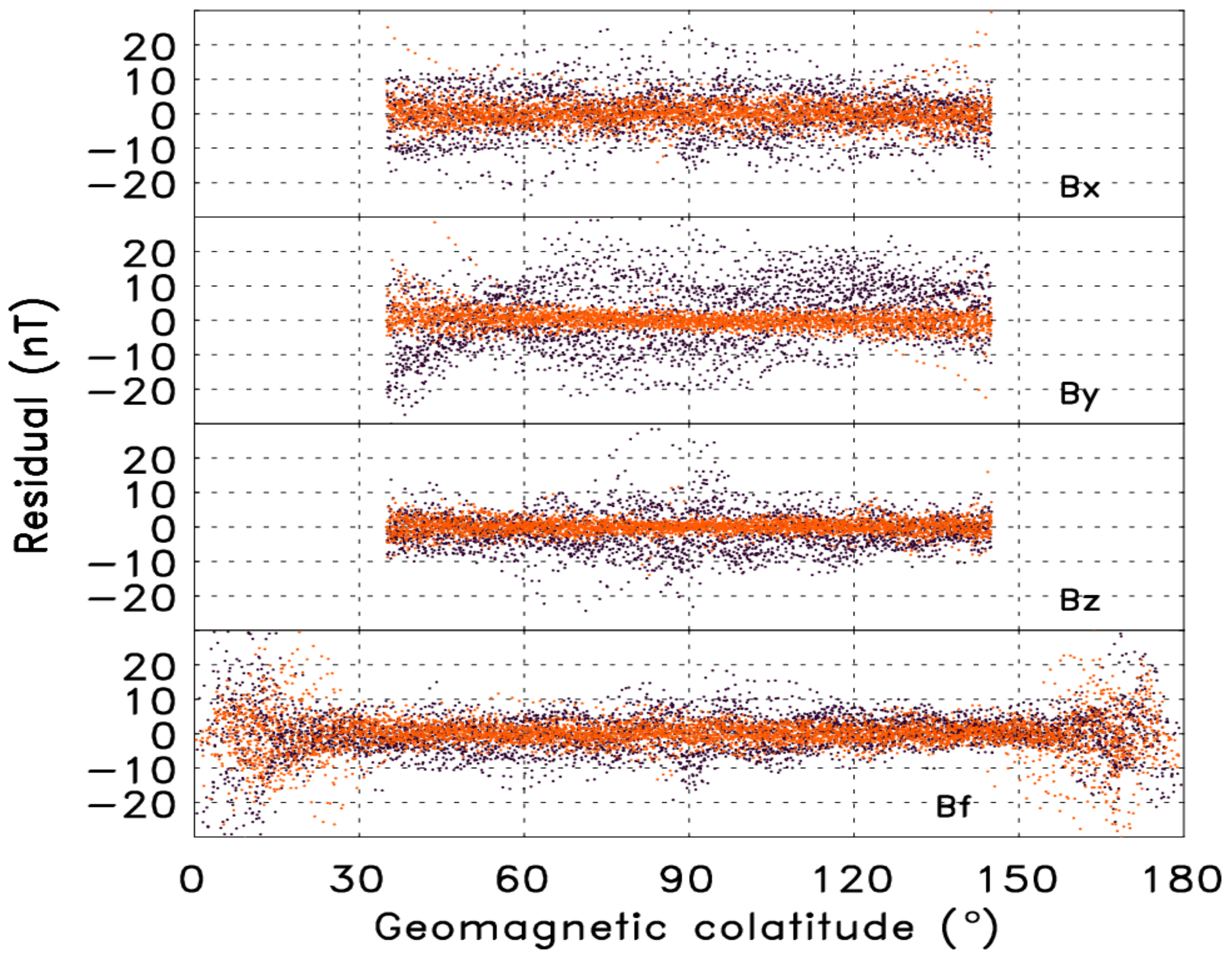


Figure 2 Data residuals of SHA model in Group (a) with respect to geomagnetic colatitude, using the Sat_A data on 1st-11th April 2017 within 11:00-12:00 LT at dayside and within 23:00-24:00 LT at nightside. From top to bottom are the residual of Bx, By, Bz, and Bf components in NEC coordinates. The residuals at dayside are plotted in purple, while the ones at nightside in orange.

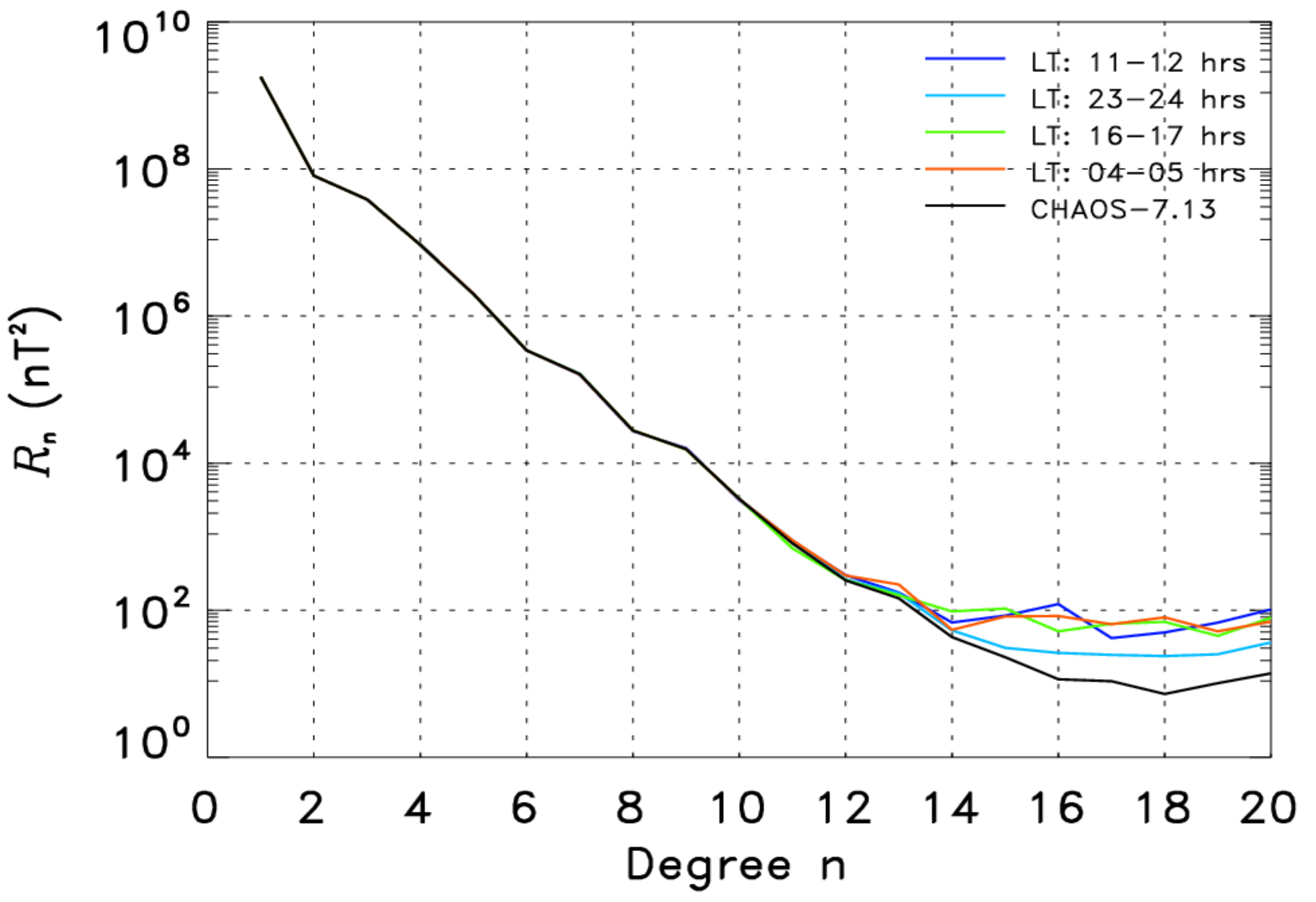
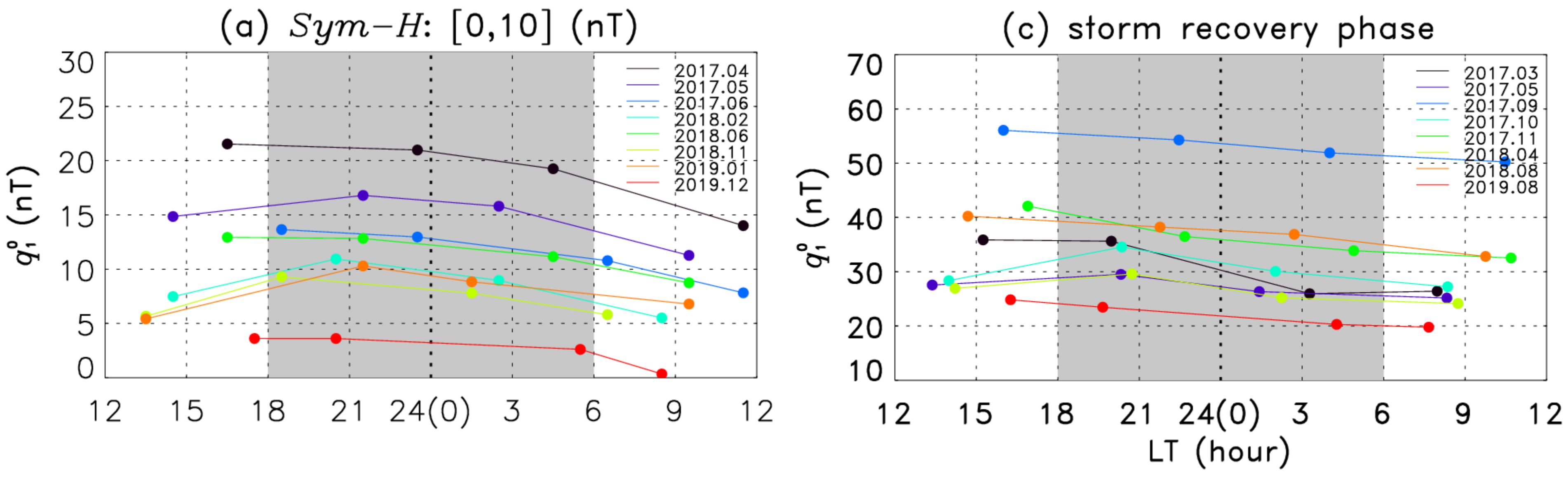


Figure 3 The spatial spectra of the four internal model coefficients in Group (a). These four models are built with the data on 1st-11th April 2017. The spectra of CHAOS-7.13 model is also shown in black.



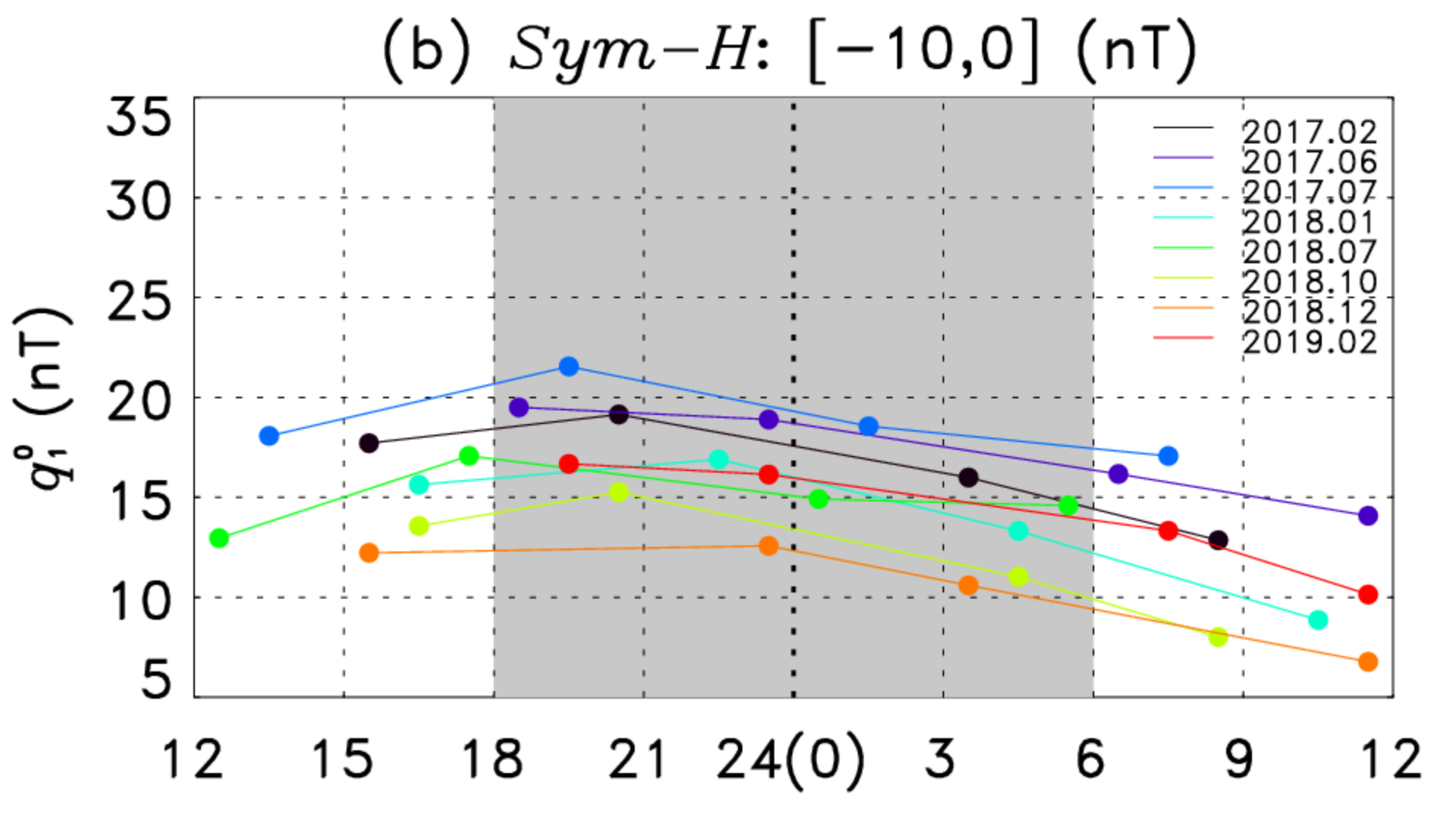


Figure 4 The value of in three groups of models versus local time. The shadow region demonstrates the nighside sector.

The peak value of q_{10} appears at the dusk-midnight sector, while the valley is located at the dawn-noon sector. Moreover, apparent energy of is seen in the afternoon sector, which is comparable to that in the postmidnight sector.

Conclusion

Stronger magnetic values are found at premidnight sector in quiet times, while at afternoon sector during recovery phase. The magnetic signals stay at lower level at postmidnight and morning sectors. The dawn-dusk asymmetry of ring current is the most pronounced feature that affects the trapping and loss of charged particle in inner magnetosphere.

Reference

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