Layered structure of near equatorial, ring current density and its ionospheric coupling: multi-spacecraft observations (X4.254)

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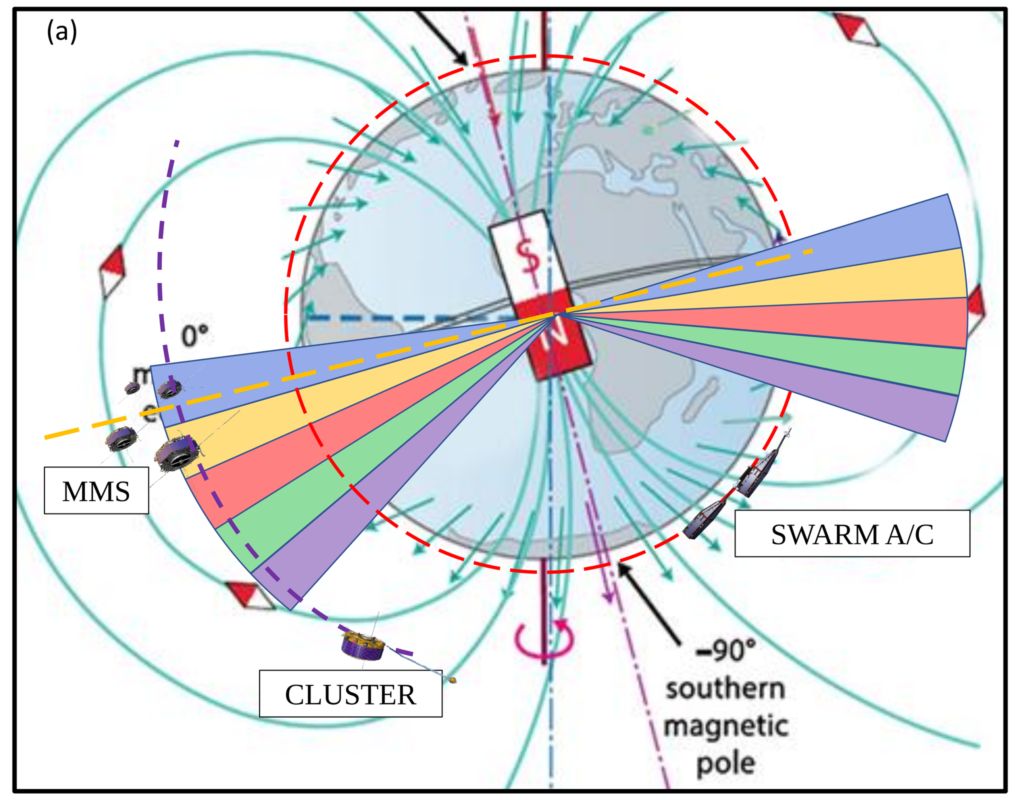
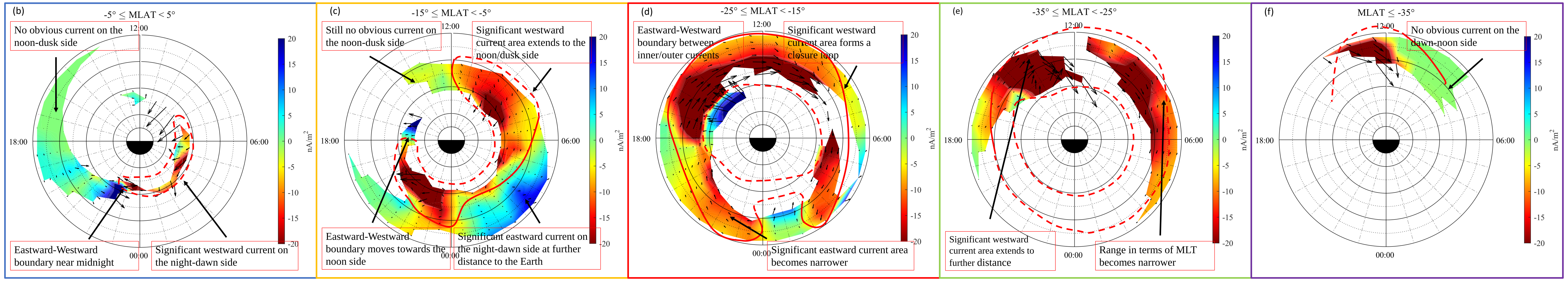
Abstract: The Earth’s ring current forms a complex current system at the boundary of the inner magnetosphere. It is highly dynamic because of the interaction between the solar wind with the Earth's magnetosphere (the influence of space weather), while its morphology depends on the nature of the magnetospheric-ionospheric (M-I) coupling, generating field-aligned currents (FACs). Its behavior can therefore have a huge impact on the terrestrial environment. According to Ampere's law, these currents can be directly measured by perturbations in the magnetic field using multi-spacecraft observation techniques. We have analyzed the magnetic field data from the four MMS spacecraft in their small-sale configuration to obtain the in-situ current density and have carried out statistical analysis from several years of data. The form of the current density distribution and its changing nature has been investigated. Our results show that the current density exhibits a three-dimensional layered structure in the ring current region. The significant westward current on the day side flows to higher magnetic latitudes and complete closure there rather than to the magnetic equator. There are some differences between geomagnetic quiet period and storm period on current density, but the basic spatial structure remains similar and compares well with previous space mission data. Comparison with Swarm data at low Earth altitudes, we found that the stratification is consistent with the distribution of the R2 field-aligned currents seen both adjacent to the ring current and at ionospheric altitudes (at Swarm). In addition, significant continuous eastward currents exist in some latitudes and some regions, indicating the complexity of the ring current. Some of them can be explained by the formation of banana currents.

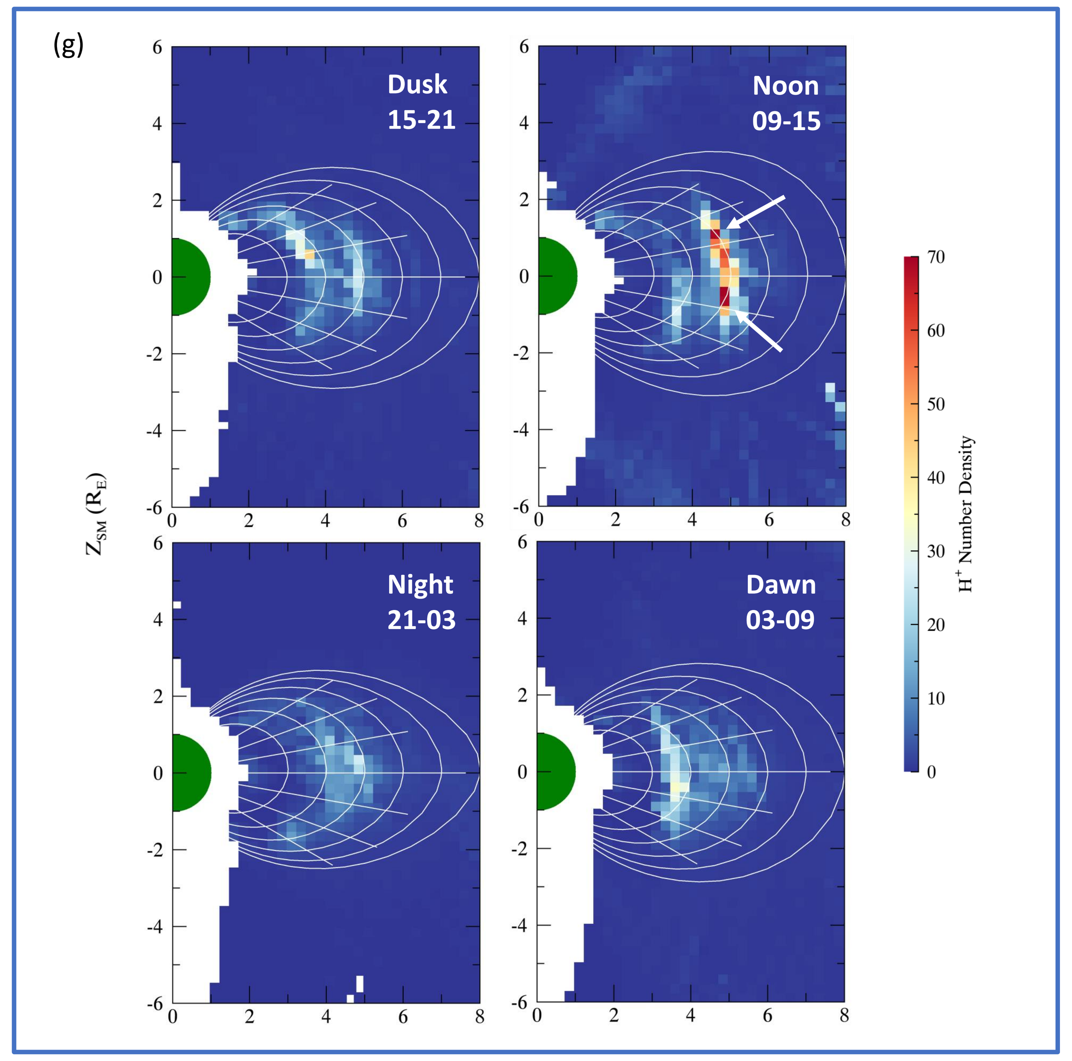
Methodology: Direct comparison of results of three missions



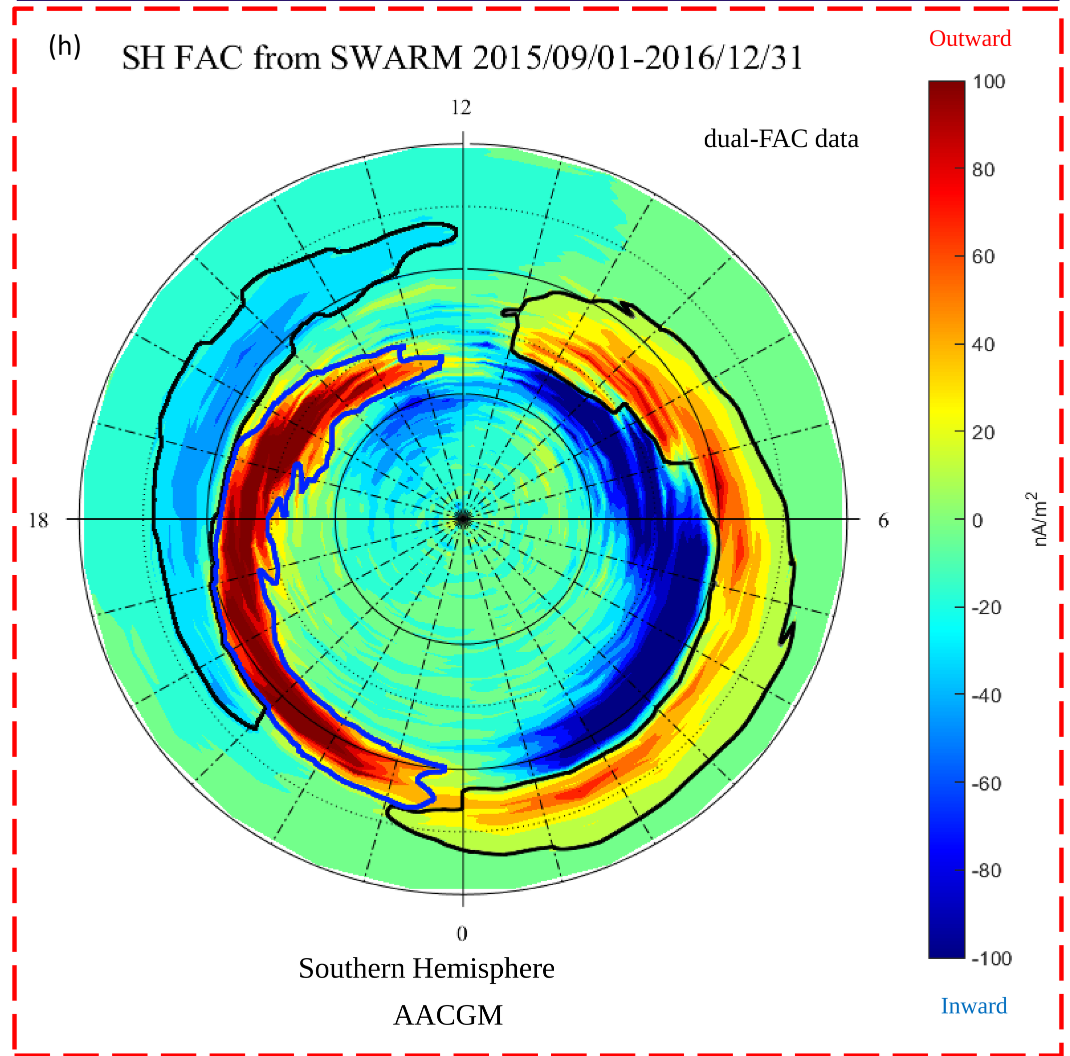
MMS result: Statistical results of Current Density for different ranges of MLAT are shown below: these show the layered structure of the RC densities away from the equatorial plane



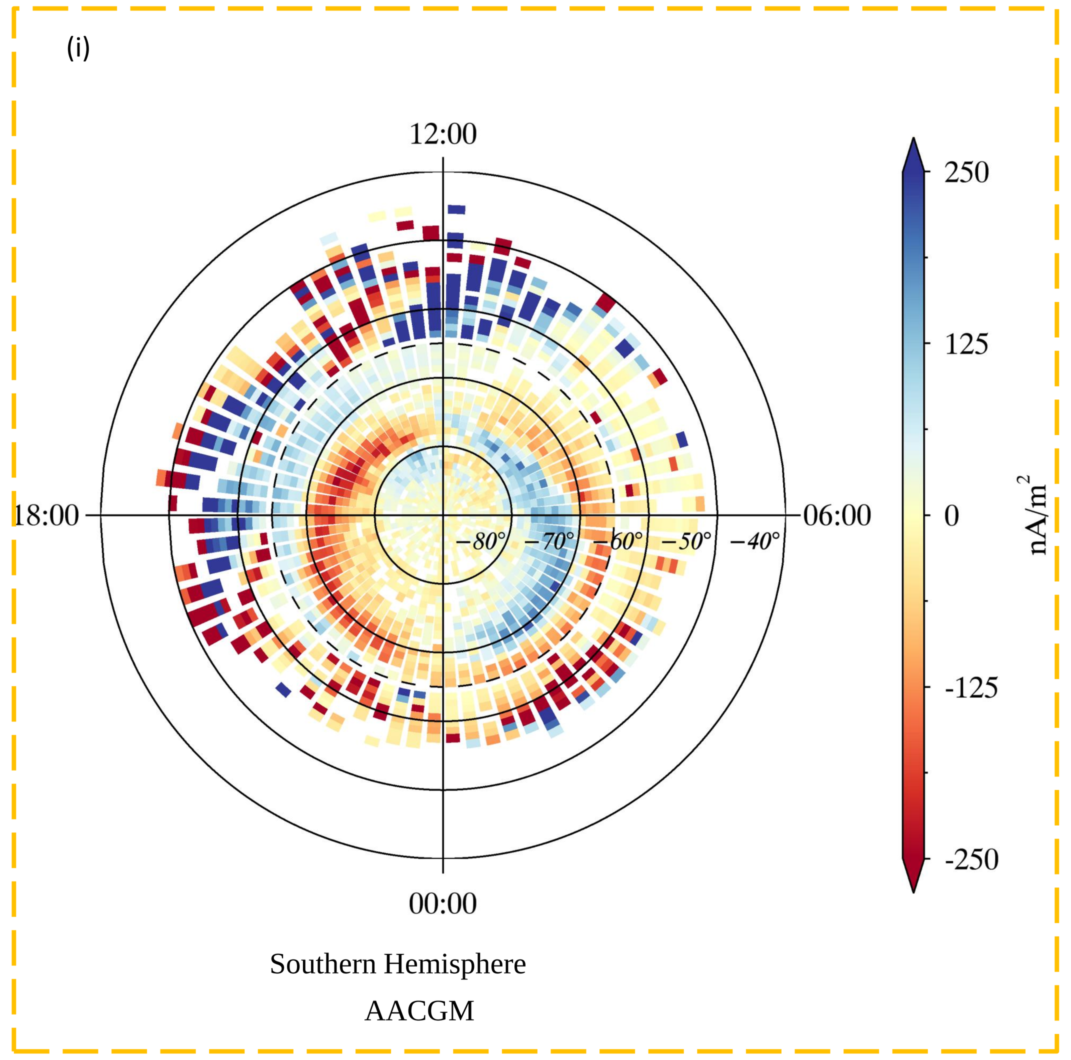
Cluster result: Statistical H+ Number Density for 25eV-40keV. Data from C4_CIS_CODIF_HS_H1 2001-2019



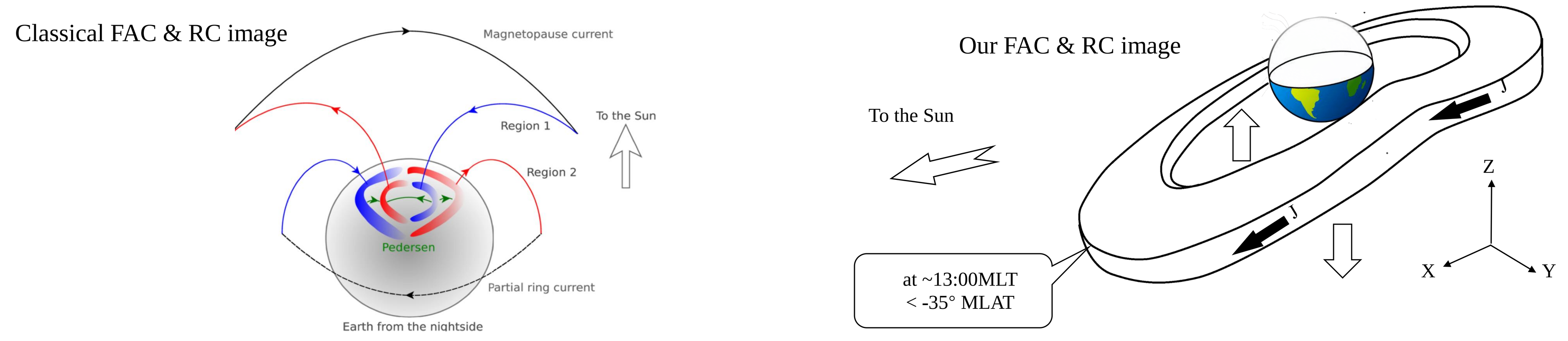
Swarm result: mean Field-aligned currents (FACs) for the corresponding period of the MMS sampling.



Comparison of Swarm & MMS FACs: natural transition in most regions of -65° MLAT.



Discussion:



1. We can calculate the *in situ* current density in and adjacent to the Earth’s RC with the Curlometer method using data from the FGM and have made statistics to get the current distribution near the equator. Thanks to the small spacing of the MMS, the current behavior at different MLATs can be clearly demonstrated. It shows that the RC has a warp structure. On the dusk side, the RC flows from the equatorial plane near the midnight to middle latitude near the noon (current density reaches peak there too), and on the dawn side, the ring current gradually flows lower and back to the equatorial plane near the midnight. Statistical H+ number density for low energy from 19 years of Cluster CIS data shows this similar trend.
2. By comparing the MMS RC distribution with Swarm's dual-FAC statistical results in the polar region, it can be seen that the influence area of R2 FACs overlaps with the RC region for the most part. We can do some qualitative analysis based on the results, but we have not yet performed a quantitative analysis.
3. The FACs adjacent to the RC at MMS are difficult to separate and map to both R1 and R2 depending on the MLAT range. However, they do follow qualitatively the low altitude R1/R2 pattern for the MMS data period.
4. Due to limitation of the MMS orbit, the statistical results cannot cover the whole space, and especially there is a lack of data for a significant part of the low MLAT region. Therefore, the behavior of current at low MLATs, especially the night side, is not clear.
5. For less than a quarter of the bins, the data are normally distributed, suggesting that other factors affect current density, and that using this limited data is difficult to solve it through other filters. The statistical rigor is not perfect. But using the median and the mean shows the same current trend.
6. The morphology of the current density shown in our cartoon is based solely on existing statistics. We consider that the MMS orbit only covered the southern hemisphere over slightly longer radial distance. We expect the actual current should be an approximately symmetrical morphology.