Statistical characteristics and forming mechanisms of trunk structure of ring current ions: Arase ion observations

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The distribution of ring current ions is controlled by transportation, acceleration and loss processes in the magnetosphere. Various structures in the energy-time spectra of ion fluxes are observed by Earth-orbiting satellites. Besides the well-known structures such as “nose” or “wedge” structures, the “trunk” structure was found by Van Allen Probes. The structure looks like an elephant trunk and the energy of peak flux decreases toward the Earth along a satellite trajectory. A case study by Van Allen Probes showed that trunk structures are seen in energy spectra of helium and oxygen ions. However, the detailed characteristics of the trunk have not been well understood, and a statistical survey using long-term observation data is necessary to examine the details. In this study, we investigate characteristics of the trunk structure using the Low-energy particle experiments-ion mass analyzer (LEPi) / Medium-energy particle experiments-ion mass analyzer (MEP-i) onboard the Arase satellite for the period from April 2017 to March 2019. A number of trunk structures were identified in helium and oxygen ions as well as protons.

We analyze geomagnetic activity, local time, latitude and L-value dependences of the trunk. The minimum L-shell point of the trunk is distributed mostly around L = 2.0 –2.5 off the equator, extending from dusk to pre-midnight. Geomagnetic storm and substorm dependences are similar between the event and the non-event periods. We also perform particle backward tracing simulations using a dipole magnetic field and a SAPS electric field model in addition to some standard empirical models of large-scale convection electric field. As a result, we show that the trunk structure can be formed when the Alfven layer is deformed due to a local and temporally enhanced electric field.

The previous study suggested that an impulsively enhanced electric field or a temporary gap of injection from the tail region combined with the charge exchange process could cause the formation of the trunk. However, our result suggests a different generation mechanism: Temporary and local electric field enhancements causes the transportation of ions to low L-shell region and the formation of trunk structure.

Beside the trunk structures, “inverse trunk” in which the energy of peak flux increases in the lower L-shell are also found from the Arase observations. We show statistical characteristics of trunk and inverse trunk structures on the basis of the Arase observations and the forming mechanism of Trunk shown by simulations.

Keywords: ring current, Arase satellite, structure on E-t diagram, Trunk structure, simulation, Electric field

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