Geometric and dynamic properties of interchange reconnection in the Earth's magnetosphere

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The concept of interchange reconnection was originally introduced in solar physics to represent reconnection between closed field lines and open field lines of the Sun. The same field line topology also applies to the Earth, although interchange reconnection in the terrestrial magnetosphere is less than familiar. The name "interchange" comes from its feature that the open/closed topologies of the two reconnecting field lines interchange at the time of reconnection. Exactly the same topological interchange occurs at reconnection between interplanetary magnetic field (IMF) lines and open geomagnetic field (so-called lobe) lines. Thus, the two reconnection processes are called "interchange-type" reconnection collectively. Interchange-type reconnection occurs on a portion of a separatrix that is discontiguous to separators, which contrasts with "Dungey-type" reconnection that occurs just on a separator. The purpose of this paper is to clarify realistic geometry of interchange-type reconnection in the magnetosphere, together with its dynamics. We particularly aim at lobe-to-closed reconnection (original interchange reconnection) during northward IMF periods. Using the Reproduce Plasma Universe (REPPU) code, under IMF conditions of B=6nT (total intensity) and $\theta = 20^{\circ}$ (clock angle), we obtained a quasi-steady magnetosphere associated with reciprocal cells circulating in the closed field line region of the ionosphere. The global magnetic topology of the magnetosphere is characterized by two magnetic null points and two separators connecting the nulls. We traced the separatrix surface emanating from each null (Σ_A from the northern null and Σ_B from the southern null), using a geodesic level-set method with high precision. The separators are determined as the intersection of Σ_A and Σ_B. In each hemisphere, interchange reconnection occurs on the lobe-closed boundary portion of Σ_A or Σ_B. We visualized field-aligned electric fields on Σ_A or Σ_B and plasma flow crossing them. This visualization enabled us to identify the so-called X line of reconnection. The cross-flow direction reverses across the X line. Field lines participating in interchange reconnection converge along the X line on the separatrix, forming a so-called guide field. Although this field line configuration is theoretically expected, its realistic geometry was elucidated for the first time by this study.

Keywords: magnetic field topology, interchange reconnection, MHD simulation

