Rapid enhancement of energetic oxygen ions in the inner magnetosphere during substorms

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Satellite observations show that energetic (greater than 100 keV) O^+ ions are rapidly increased in the inner magnetosphere during substorms. The ultimate source of O^+ ions is the Earth's ionosphere, so that O^+ ions must be accelerated from ˜eV to 100s keV somewhere in the magnetosphere. A fundamental question still arise regarding why O^+ ions are accelerated and transported to the inner magnetosphere. We simulated substorms under two different solar wind conditions by using the global MHD simulation developed by Tanaka et al. (2010, JGR). The solar wind speed is set to be 372 km/s for Case 1, and 500 km/s for Case 2. In both cases, the MHD simulation result shows that the dawn to dusk electric field is enhanced in the night side tail region at greater than 7 Re just after the substorm onset. In particular, the electric field in the inner region (˜7 Re) is highly enhanced by the tension force because of relatively strong magnetic field together with curved field lines. The strongest electric field takes place near the region where the plasma pressure is high. We performed test particle simulation under the electric and magnetic fields for Cases 1 and 2. O^+ ions are released from two planes located at 2 and -2 Re in the Z direction in the tail region. O^+ ions released at the two planes represent outflowing stream of O^+ ions escaping from the Earth. The distribution function at the planes is assumed to be drifting Kappa distribution with temperature of 10 eV, the density of 10^5 m^{-3}, and the parallel velocity given by the MHD simulation. In total, around a billion of particles are traced. Each test particle carries the real number of particles in accordance with the Liouville theorem. After tracing particles, we reconstructed 6-dimensional phase space density of O^+ ions. We obtained the following results. (1) Just after substorm onset, the differential flux of O^+ ions is almost simultaneously enhanced in the region where the electric field is strong. (2) The kinetic energy increases rapidly to 120 keV for Case 1, and 200 keV Case 2 in the inner magnetosphere. (3) On the dayside, the pitch angle anisotropy of O^+ ions increases with radial distance. We will discuss the acceleration processes and generation mechanisms of pitch angle anisotropy of O^+ ions in more detail, and the overall contribution to the ring current.