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A global MHD simulation study of the ion outflow channels from the Martian ionosphere

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Mars has no global magnetic field, leading to the direct interaction of the solar wind with its upper atmosphere. As a result of the direct interaction escape of planetary atmosphere occurs. In the past, the Phobos2 spacecraft observed the acceleration and outflow of ions of planetary origin, and the oxygen loss rate from present-day Mars was estimated about 3×10^{25} ions/s [Lundin et al., 1989]. Also, Ion Mass Analyzer (IMA) aboard Mars Express (MEX) observed a large amount of heavy ions such as $CO_2{}^+$ escaping from the Martian ionosphere [Carlsson et al., 2006].

A variety of outflow processes that result from the direct interaction of the solar wind have been proposed, such as the ion pick-up process, sputtering, outflow from magnetic anomalies, and outflow of the ionospheric ions. Among them, the outflow process of low energy ions ($<\sim$ 10eV) from the ionosphere is especially uncertain because observations are technically difficult. Therefore, we performed a three-dimensional visualization using the result of a global magnetohydrodynamics (MHD) simulation of the Mars-solar wind interaction [e.g., Terada et al., 2009], and analyzed the outflow channels and acceleration mechanisms of the low energy ionospheric ions. The MHD simulation treats plasma as a fluid, and we used it because the fluid approximation relatively holds for the low energy ions due to their small Lamor radii. As results of a three-dimensional visualization, we found that a streamline extending from the dayside ionosphere goes through near a magnetic pole of Mars, and splits into east and west in the vicinity of the equatorial plane in the night side ionosphere and coils up. It eventually forms four vortices. Bulk velocity along these vortices increase near the ionopause, extending to outer space. In this study, at first, we followed the streamlines and examined where the ions originating from the dayside ionosphere were accelerated. Then, we chose some streamlines, checked the values of the bulk velocity, the magnetic field, and the plasma pressure along them, and quantitatively evaluated all the terms of the equation of motion. Thereby, we examined where and by what force the ions of the dayside ionospheric origin were accelerated over the chosen streamlines.

In this presentation, we will present the results of the analysis of the outflow channels and the acceleration mechanisms of the ionospheric ions at Mars using the global MHD simulation.

Keywords: Mars, ionosphere, atmospheric outflow, MHD simulation