多流体MHDシミュレーションに基づく太陽風磁場進入時の火星電離圏CO2+鉛直分布にイオン種間衝突が及ぼす影響の研究

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Effects of ion-ion collisions on vertical CO2+ profiles in Martian ionosphere under magnetic field penetration: Multi-fluid MHD

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The escape of the planetary atmosphere is an important phenomenon related to evolution of the atmosphere, and numerical simulations are an effective method to understand the global atmospheric escape processes. Since Mars does not have a global intrinsic magnetic field, the upper atmosphere interacts directly with the solar wind. The cold ion outflows the ionosphere driven by the interaction is considered as an important escape mechanism for heavy ions from Mars. In order to realize the observed large amounts of $CO_2{}^+$ escape observed by Mars Express [Carlsson, Icarus, 2006] through the outflows, high density of $CO_2{}^+$ at high-altitude ionosphere is required. The ionospheric model developed by Fox and Hac [2010] assumed velocity difference for each ion species in the ionosphere to reproduce the density distribution of heavy ions including $CO_2{}^+$ in high-altitude ionosphere. This result suggests velocity difference is important to reproduce the $CO_2{}^+$ density in high-altitude ionosphere. Najib et al. [JGR, 2011] used Multi-fluid MHD, which is the model allows each ion species to take individual velocities, to simulate the solar wind-Mars interaction. The collisions between different ion fluids (ion-ion collisions) was not included in their model. In our previous study, we developed Multi-fluid MHD code that includes the ion-ion collisions, and applied it to simulations of Martian ionosphere under conditions of no magnetic field. The results suggested that the velocity difference between ion species enhances upward transport of $CO_2{}^+$ and the ion-ion collision limits the upward transport of $CO_2{}^+$. This limitation is important to determine relative abundance of each ion species in the high-altitude ionosphere.

In this study, we investigate the effects of the ion-ion collision as well as the velocity difference of each ion species on the vertical density profile of $CO_2{}^+$ under the existence of magnetic fields. In order to simulate the solar wind penetration from the above, we put the transverse magnetic field at the upper boundary of the ionosphere. We conducted three cases of the simulations. Case 1: Multi-fluid MHD including the ion-ion collisions, Case 2: Multi-fluid MHD without the ion-ion collisions, and Case 3: Multi-species MHD (no velocity difference between ion species). In the presentation, dependences of vertical profile of $CO_2{}^+$ density on the imposed magnetic field strength (equivalent to the solar wind dynamic pressure) and the boundary conditions of the vertical velocity at the upper boundary will be reported.