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Effects of ion-ion collisions on vertical distribution of CO2+ in Martian ionosphere based on multi-fluid MHD simulation

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Comparison of the mass fraction of CO2 and N2 with regard to the total mass of each terrestrial planet suggests importance of the atmospheric escape to space in Martian atmospheric evolution [Chassefiere et al., 2006]. It has been considered that heavy CO_2^+ ions are difficult to escape based on known atmospheric escape processes. Observations of a large amount of CO_2^+ ion escape by the Mars Express thus challenged the existing escape processes. Vertical distribution of CO_2^+ density in the ionosphere is one of important factors that determine the rate of CO_2^+ escape. Chemical reactions in ionosphere have been implemented in previous studies using multi-species MHD simulations [e.g., Ma et al., 2004; Terada et al., 2009]. The velocity difference between ion fluid cannot be reproduced by the multi-species MHD approximation. On one hand, the importance of vertical transport in the upper ionosphere (>300km altitude) was pointed out by some ionospheric models [Fox and Hac, 2009]. Multi-fluid MHD code [e.g., Najib et al., 2011] can solve such ion-species dependent velocity.

In this study, we developed a multi-fluid MHD simulation code. Our code includes ion-ion collisions in order to investigate their effects on the vertical distribution of CO_2^+ density in the Martian ionosphere. Three cases of the simulation runs are carried out: Multi-fluid MHD with ion-ion collision (Case1), multi-fluid MHD without ion-ion collision (Case2), and all ion species have the same vertical velocity corresponding to multi-species approximation (Case3). We compared the results after each simulation run reached to a quasi-steady state. The CO_2^+ density at altitude 460 km were turned out to be 82, 190, and 11 cm^{-3}, respectively for the Cases 1-3. The results suggest that inclusion of ion-ion collision is important to reproduce the realistic CO_2^+ transport from lower to upper ionosphere.

Keywords: Mars, ionosphere, Atmospheric escape, Multi-fluid MHD