R009-22
B 会場 ：11/7　 AM2 （10:45-12:30）
11:15〜11:30

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Multifluid MHD simulation of the effects of a dipole field on ion escape at ancient Mars

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Escape of the ionized atmosphere, ion escape, played an important role in atmospheric loss and climate change at ancient Mars due to intense solar X-ray and EUV (XUV) radiation and solar wind from the young Sun. The distribution of the crustal magnetic field on the surface indicates that ancient Mars once had an intrinsic magnetic field. In addition to the solar XUV and solar wind conditions, the presence of an intrinsic magnetic field affects ion escape. Our previous studies (Sakata et al., 2020; Sakata et al., 2022) investigated the effects of the dipole field on ion escape processes and rates under the ancient solar XUV and solar wind conditions based on global multispecies magnetohydrodynamics (MHD) simulations. They revealed that the ion escape rates depend on the ratio of the dipole field's magnetic pressure at the equatorial surface to the solar wind dynamic pressure. The effects are more pronounced on the escape of molecular ions ($O_2{}^+$, and $CO_2{}^+$) by ionospheric outflow. However, the multispecies MHD model neglects kinetic effects and different dynamics among ion species. The outflow from the ionosphere often occurs in a region where the solar wind H^+ inflow and the planetary ion outflow coexist. The multispecies MHD simulations may therefore underestimate the ionospheric outflow.

We developed a new 3D global multifluid MHD model with the cubed sphere grid. It solves the continuity, momentum, and energy equations for five ion species (solar wind H^+, planetary H^+, O^+, $O_2{}^+$, and $CO_2{}^+$), the induction equation for the magnetic field, and the electron pressure equation. It considers the ionization processes, chemical reactions, and collisions which are important in the ionosphere. In this study, we assumed the ancient solar XUV and solar wind conditions used in Sakata et al. (2022). The solar wind density and velocity were 700 cm^{-3} and 1400 km s^{-1}, respectively. The interplanetary magnetic field was 20 nT in the away-sector of the Parker spiral. The solar XUV radiation was 50 times higher than the current value. The two simulation cases were conducted: the case with no dipole field and the case with a weak dipole field with the strength of 100 nT at the equatorial surface. We also conducted the multispecies MHD simulations on the same grid system for comparison.

The multifluid MHD simulation results show that the asymmetric flux distribution of heavy ions (O^+, $O_2{}^+$, and $CO_2{}^+$) due to the convectional electric field of the solar wind, which is not seen in the multispecies MHD simulations. We will focus on the difference in the escape processes and rates and its implication for the effects of an intrinsic magnetic field on ion escape.

References

Sakata, R., Seki, K., Sakai, S., Terada, N., Shinagawa, H., & Tanaka, T. (2020), Effects of an intrinsic magnetic field on ion loss from ancient Mars based on multispecies MHD simulations. Journal of Geophysical Research: Space Physics, 125, e2019JA026945. doi:10.1029/2019JA026945

Sakata, R., Seki, K., Sakai, S., Terada, N., Shinagawa, H., & Tanaka, T. (2022). Multispecies MHD study of ion escape at ancient Mars: Effects of an intrinsic magnetic field and solar XUV radiation. Journal of Geophysical Research: Space Physics, 127, e2022JA030427. https://doi. org/10.1029/2022JA030427