Study of ion composition in the polar plume from Mars based on MAVEN observations

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Mars climate was warm and had water on its surface about 4 billion years ago, but there are no liquid water on the surface at present. Escape of the atmosphere to space is considered as the main cause of this climate change. However, the mechanism of the large amount of atmospheric loss is far from understood. Ion escape is one of the important candidates of such mechanism. There are three channels of the ion escape, namely, tailward escape, pickup ion, and polar plume. Polar plume ions are accelerated by solar wind electric field and escape to +E hemisphere of the Mars-Sun-Electric field (MSE) coordinates. It is estimated by Dong et al., (2015) that the escape rate is 23% of the total ion escape. This is not negligible in order to understand ion escape from Mars. However, the composition of the plume is unknown. To fully understand the mechanism of polar plume, it is important to study the composition of the plume.

The purpose of this study is to assess the suggested mechanism of the polar plume based on MAVEN (Mars Atmosphere and Volatile EvolutioN) observations. Spatial distribution of the ion number density ratio can be the evidence that plume is accelerated by electric field because the trajectory of accelerated ions depends on the ion mass. Polar plume contains O^+, O_2^+, and CO_2^+ ions. We focused on molecular ions (O_2^+ and CO_2^+) originating from the ionosphere, since O^+ has corona as its source and its spatial distribution becomes complicated. We analyzed observation data by STATIC (Supra Thermal and Thermal Ion Composition) and MAG (magnetometer) onboard MAVEN. STATIC can measure ion distribution functions with mass discrimination. We selected 12 orbits, in which the plume is observed continuously, from two years of data (from December 2014 to December 2016). To derive CO_2^+ number density, we used fitting method invented by Inui et al., (2018). By fitting a log-normal distribution to O_2^+ count data, we eliminated O_2^+ contamination in the CO_2^+ mass range.

In the event on December 23, 2014, MAVEN moved from the dayside solar wind region to nightside induced magnetosphere in the +E hemisphere of the MSE coordinates. During this event, CO_2^+/O_2^+ number density ratio gradually decreased from ˜50 % to ˜0.2 %. This tendency is consistent with difference of the trajectories of O_2^+ and CO_2^+, when these ions are accelerated from the same position by the solar wind electric field. We also found high density CO_2^+ plume event in which the CO_2^+ number density is ˜1 cm^{-3} and its ratio to O_2^+ is ˜500 % at the maximum in the dayside solar wind. We will also report on the statistical tendency of the 12 plume events as well as their dependence on solar wind parameters.

Keywords: Mars, MAVEN, atmospheric escape, carbon dioxide, polar plume