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 is no 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., [2017] that the escape rate is 20-30% of the total ion escape depending on the solar EUV radiation. This is not negligible in order to understand ion escape from Mars. 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 investigate contribution of molecular ions (O_2^+ and CO_2^+) to the polar plume. The source of O_2^+ and CO_2^+ is the ionosphere only, while O^+ has the neutral corona as its source in addition to the ionosphere. Thus, contribution of molecular ions to the polar plume can be different from that of O^+. Spatial distribution of the ion number density ratio between O_2^+ and CO_2^+ is expected to change systematically if the plume is accelerated by electric field, since the trajectory of accelerated ions depends on the ion mass. We analyzed observation data by STATIC (Supra Thermal and Thermal Ion Composition), MAG (magnetometer) and SWIA (Solar Wind Ion Analyzer) onboard MAVEN (Mars Atmosphere and Volatile EvolutioN). STATIC can measure ion distribution functions with mass discrimination. We selected a few orbits, in which the plume with high CO_2^+ flux is observed continuously, from two years (from December 2014 to December 2016) of data. To derive CO_2^+ number density, we used a 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 August 28, 2015, MAVEN moved from the nightside induced magnetosphere to dayside solar wind region in the +E hemisphere of the MSE coordinates. During this event, CO_2^+/O_2^+ number density ratio increased with increasing sunward distance in the main plume region. This tendency is consistent with the plume acceleration by the solar wind electric field as previously proposed. In this event, maximum O_2^+ and CO_2^+ fluxes are 1.2×10^6 and 3.6×10^6, respectively. These fluxes are about one order of magnitude higher than the average O^+ flux in the polar plume reported by Dong et al., [2017]. It should be noted that higher CO_2^+ flux than O_2^+ is partly caused by limited coverage of FOV (field of view) of STATIC during the plume event. In the event on December 17, 2016, in which the STATIC FOV was good, the maximum O_2^+ and CO_2^+ fluxes are 7.2×10^6 and 2.2×10^6, respectively. The higher maximum flux of O_2^+ than CO_2^+ is qualitatively consistent with ion species ratio in the source ionosphere. In order to discuss the acceleration and transport mechanism of the molecular ion plumes, we will also report on the results of ion trajectory tracings in the electric and magnetic field configuration obtained by multi-species global MHD simulation.

References:

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