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太陽風電場が火星電離圏イオンの降り込みに与える影響の統計解析研究
Effects of the solar wind electric field on heavy-ion precipitation onto the Martian atmosphere: A statistical survey

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The solar wind can directly interact with the Martian upper atmosphere, since Mars does not possess a global intrinsic magnetic field [e.g., *Acuna et al*., 1998]. Atmospheric escape phenomena induced by the solar wind interaction have been observed by Phobos-2 at solar maximum, and recently by Mars Express (MEX) at solar minimum [e.g., *Lundin et al*., 1989; *Barabash et al*., 2007]. Escape rates of planetary ions estimated by both spacecraft indicate a large dependence on the solar wind conditions [e.g., *Barabash et al*., 2007; *Lundin et al*., 2008]. It has been known that escaping planetary ions, which are picked up by interplanetary magnetic field (IMF) in the solar wind, are distributed highly asymmetrically in terms of the convective electric field [*Barabash et al*., 2007]. In addition to escaping ions, ions precipitating onto the Martian upper atmosphere should also contribute to atmospheric escape because they collide with atmospheric neutral particles, giving some particles sufficient energy to escape the planet [e.g., *Luhmann et al*., 1992]. This process is referred as ion sputtering. Ion sputtering could have been a significant escape process for ancient Mars due to the extreme solar EUV radiation, according to some results of numerical simulations [e.g., *Luhmann et al*., 1992; *Leblanc and Johnson*, 2002]. However, there are no conclusive in situ measurements of sputtering for Mars.

Precipitating planetary heavy ions with energies of up to a few keV were observed by MEX predominantly during CIR passages [*Hara et al*., 2011]. *Hara et al*., [2011] suggested that the flux of precipitating heavy ions is enhanced during CIR events because the gyroradius of picked-up ions is decreased to values comparable to the radius of Mars by the compressed IMF. The direction of the convective electric field in the solar wind should also be important for the behavior of picked-up ions. However, MEX does not carry any magnetic or electric field detectors, and therefore we cannot easily obtain the direction of the magnetic field or that of convective electric field in the solar wind.

Here we attempt to estimate the IMF orientation from MEX ion observations using the ring-like velocity distribution functions of picked-up protons of the exospheric origin [*Yamauchi et al*., 2006, 2008]. We are able to calculate the IMF orientation from the assumption that the gyration plane of these ions in velocity space is perpendicular to the IMF direction. Then, we conduct simple statistical trajectory tracings of picked up protons in physical space in order to determine the polarity of the IMF. We assume two IMF configurations (differing only in polarity) and traced a number of pickup protons. Then we can determine the polarity of IMF by inspecting which configuration better matches the observation. We also discuss the application of this method to statistically study effects of the solar wind electric field on the heavy-ion precipitation for Mars using the events in which both ring-ions and precipitating heavy ions are observed by MEX in the same orbit.

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