Atmospheric loss from the Earth's plasma mantle and its dependence on solar wind conditions

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The Earth's atmospheric loss is an important phenomenon affecting the evolution of the terrestrial atmosphere on geological timescales. This terrestrial phenomenon is driven by atmospheric ions, mainly oxygen ions (O^+) heated through different processes and with sufficient energy to escape the gravity, and becoming ion outflow. The outflowing ions are observed at low and high altitudes in the open magnetic field line regions called the polar cap, cusp and plasma mantle. The polar cap and plasma mantle configuration changes under strong solar wind conditions (high density and velocity), which allows higher solar wind flux to penetrate these regions. However, it has not well understood how strong solar wind affects the O^+ escape rate. Thus, this study aims to answer how the O^+ escape rate depends on the solar wind parameters.

Using the oxygen data from CODIF instrument onboard the European Spacecraft Cluster and solar wind data from ACE, we defined solar wind constraints by plotting the distribution between the solar wind velocity and density for time period with available O^+ observations in the plasma mantle. We estimated the O^+ flux for the defined solar wind constraints. Analogously, we also investigated the O^+ escape rate dependence on solar EUV flux (defined as the ratio of the EUV intensity over the photon energy) and the solar wind dynamic pressure. For the first solar wind constraints, we found that the O^+ flux in the plasma mantle increases with increased solar wind velocity and density. Consequently, the O^+ escape rate follows this tendency and is higher as well. Consistently, the O^+ escape rate also increases with solar wind dynamic pressure in contrast to the EUV flux that does not have a significant influence.

Our results imply that the higher solar wind flux penetrates into the magnetosphere, the higher O^+ rates. Therefore, atmospheric loss depends on solar wind conditions. Considering that solar wind from the young Sun was stronger, solar wind driven O^+ escape can be expected to have had a significant influence on the evolution of the Earth's atmosphere. Questions remain regarding how the intrinsic magnetic field protect Earth from significant solar wind penetration and our atmosphere from atmospheric loss? Will the atmosphere continue to lose O^+ on a longer timescale and become a Martian-like atmosphere?