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The EUV impact on ionosphere: what does present observations indicate for atmospheric evolution of early Earth and Exo-Earths

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Observations up to date on the ion escape from the Earth, Mars, and Titan show unexpected variability of the solar EUV dependent atmospheric escape. The non-thermal ion escape from the Earth's ionosphere shows unexpectedly large changes between solar minimum and solar maximum, particularly for atomic oxygen ions compared to atomic hydrogen ions. Comparison of MEX and Phobos-2 also indicates two order of magnitude differences between solar maximum and solar minimum. On the other hand, the recently-reported change of the Venus ionopause height during the solar cycle indicates the variation of thermal and non-thermal escapes out of phase from the solar cycle. In fact, a massive ion loss is observed from Titan where solar EVU is very weak. These observations and the present knowledge on the ion escape from the Earth, Mars, and Titan has been synthesized to consider the atmospheric evolution of early Earth and exoplanets within habitable zones with extreme solar UV conditions. Particular stress is given on the roles of the ionosphere and its drastic response to the solar/solar wind parameters, both having been underestimated in existing models of ancient atmospheric escape 4 billions years ago. We also discuss possible extra ionization by, e.g., critical ionization velocity mechanism.