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EGU24-17183, updated on 06 Feb 2025
https://doi.org/10.5194/egusphere-egu24-17183
EGU General Assembly 2024

Evolution of Atmospheric Oxygen Escape on Earth since the Paleoproterozoic Era

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Understanding atmospheric escape over geological timescales is essential to constrain the planet's ability to retain its atmosphere and thus sustain life. Atmospheric particles are energized through solar radiation and plasma interactions between the solar wind, the Earth's magnetosphere, and ionosphere, escaping through various mechanisms.

For Earth, several missions provided measurements of the oxygen escape rate. However, measurements are for current solar and planetary conditions that strongly differ from the past conditions (e.g. stronger solar wind, higher solar EUV radiation). The main challenge to estimate the past escape rate is to extrapolate current measurements to the past solar system environment.

Since the Great Oxidation Event, 2.45 Gyr. ago, there is a significant amount of oxygen in the atmosphere. The goal of this study is to assess the stability of oxygen on Earth concerning atmospheric escape. We developed a semi-empirical model, which considers seven different escape mechanisms to estimate the net oxygen escape on Earth since this event. We use models available in the literature to describe the past solar wind and solar radiation, the Earth's magnetic moment history, and the Earth's exosphere evolution due to the change of solar EUV radiation while considering a constant atmospheric composition. The escape rate is calculated for these previous conditions considering a physical scaling and/or empirical formulas per mechanism.

We estimate that the total oxygen loss during the last 2.45 Gyr., reaches almost 30% of the current atmospheric oxygen content. Oxygen escape is dominated by polar processes, polar wind and cusp escape, contributing over 90% of the total loss. Polar wind is the leading erosion mechanism before ~1.5 Gyr. while escape from the polar cusp dominates at present.