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Atmospheric outflow from the terrestrial magnetosphere; implications for escape on evolutionary time scales

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The most direct interaction between the solar wind and the ionosphere is constrained to the magnetospheric cusps, causing ion outflow from the ionospheric cusps and surrounding vicinity. If the subsequent energization in the cusps is sufficient the ions will heat and accelerate enough to escape into the solar wind, either downstream in the tail or directly into the dayside magnetosheath. Cluster observations in the high altitude cusp/mantle during high solar activity conditions reveal O^+ fluxes of the order 10^{25} s^{-1} with energies high enough to eventually escape. In addition, High latitude dayside magnetosheath measurements show that a significant amount of O^+ $(0.7 \cdot 10^{25}$ $s^{-1})$ escapes directly from cusp. Some evidence of dual-lobe reconnection is observed, but only up to 5% of the observed magnetosheath O^+ is caught and brought back into the magnetosphere.

Such escape of ionospheric ions are expected to strongly depend on the ionospheric conditions and hence the geomagnetic activity. The escape rates for the two routes have been investigated as functions of geomagnetic activity, Kp. The contribution from the plasma mantle route is estimated as $3.9 \times 10^{24} \exp(0.45Kp)$ [s^{-1}], with a 1 to 2 order of magnitude range for a given geomagnetic activity condition. Extrapolation of this result – and including escape via the dayside magnetosheath – indicates an average O^+ escape of 3×10^{26} s^{-1} for the most extreme geomagnetic storms. Assuming that the range is mainly caused by the solar EUV level, which was also larger in the past, the average O^+ escape could have reached 10^{27-28} s^{-1} a few billion years ago. Integration over time suggests a total oxygen escape – from ancient times until today – roughly equal to the atmospheric oxygen content today.