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Martian oxygen escape rate as a function of upstream solar wind density: results from a hybrid model

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We investigate the dependence of oxygen escape rate at Mars on the proton density of the upstream solar wind using a parallel hybrid model. The model handles ions as particles and electrons as a massless, neutralizing fluid. The model currently contains three ion species: protons and alpha particles from the solar wind, and a heavy ion species from Martian ionosphere, which is atomic oxygen ion in this study. The interplanetary magnetic field is set to follow the typical Parker spiral at Mars with an intensity of 3 nT. The upstream solar wind velocity is 400 km/s, along the $-x$ axis. We vary the upstream proton density from n_p =0.2 cm^{-3} to n_p =25 cm^{-3} while keeping all other parameters fixed. The oxygen escape rate Q shows a negative correlation with n_p within the range $0.5 < n_p < 3.5$ cm^{-3}. The ratio between the maximum and the minimum escape rates is ∼3. Outside this density range the correlation is positive. This anticorrelation between Q and n_p within the most probable range of the upstream proton density, and the relative variation of Q are consistent with the latest experimental investigations on the same topic using the ion data from MEX/ASPERA-3 [Ramstad et al., 2014]. We also investigated cases under 500 km/s upstream velocity and CO_2^+ ions, the results are qualitatively consistent.

The modeled magnetospheric morphology reveals two competing escape channels that depend differently on the upstream density. The channel including the pickup ions and the plasma sheet intensifies with increasing upstream density. The channel including the lobe region and the boundary layer intensifies with decreasing upstream density due to a more expanded induced magnetosphere. The latter dominates the ion escape when the density is lower than ∼2.5 cm^{-3}. We also investigate the momentum transfer from the shocked solar wind to the induced magnetosphere.

References: R. Ramstad, S. Barabash, Y. Futaana, H. Nilsson, M. Holmstroem [2014]: The Martian escape rate as a function of upstream solar conditions, AGU Fall Meeting 2014, P51B-3941, San Fransisco.