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Comparing the contributions of ionospheric outflow and high-altitude production to O^+ loss at Mars

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The Mars total O^+ escape rate is highly dependent on both the ionospheric and high-altitude source terms. Because of their different source locations, they appear in velocity space distributions as distinct populations. The Mars Test Particle model is used (with background parameters from the BATS-R-US magnetohydrodynamic code) to simulate the transport of ions in the near-Mars space environment. Because it is a collisionless model, the MTP's inner boundary is placed at 300 km altitude for this study. The MHD values at this altitude are used to define an ionospheric outflow source of ions for the MTP. The resulting loss distributions (in both real and velocity space) from this ionospheric source term are compared against those from high-altitude ionization mechanisms, in particular photoionization, charge exchange, and electron impact ionization, each of which have their own (albeit overlapping) source regions. In subsequent simulations, the MHD values defining the ionospheric outflow are systematically varied to parametrically explore possible ionospheric outflow scenarios. For the nominal MHD ionospheric outflow settings, this source contributes only 10% to the total O^+ loss rate, nearly all via the central tail region. There is very little dependence of this percentage on the initial temperature, but a change in the initial density or bulk velocity directly alters this loss through the central tail. However, a density or bulk velocity increase of a factor of 10 makes the ionospheric outflow loss comparable in magnitude to the loss from the combined high-altitude sources. The spatial and velocity space distributions of escaping O^+ are examined and compared for the various source terms, identifying features specific to each ion source mechanism. These results are applied to a specific Mars Express orbit and used to interpret high-altitude observations from the ion mass analyzer onboard MEX.