PARAMETER STUDY OF PLASMA-INDUCED ATMOSPHERIC SPUTTERING AND HEATING AT MARS.

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Introduction: Atoms and molecules in Mars' upper atmosphere are lost through sputtering, caused by a flux of pick-up ions into the exosphere, dissociative recombination, and thermal escape. While all three processes occur on Mars, a detailed understanding must ascertain the relative importance of each process, due to time variations in energy and flux of the pick-up and solar wind ions. In this project, using case studies of an oxygen upper atmosphere modeled with Direct Simulation Monte Carlo (DSMC) techniques, we will describe the relative importance of momentum transfer to individual molecules and heating of the atmosphere by the incident ions.

To do this, we vary the incident plasma flux and energy based on models of the interaction of the solar wind with the Martian atmosphere. We first repeat the heating rates due to a flux of pick-up O+ examined previously ([4], [6]). These range from low fluxes seen during periods of minimal solar activity to high fluxes seen in earlier epochs during extreme events. Using a wide range of fluxes also allows us to examine the effect of penetration depths on the resulting heating and escape profiles.

In modeling atmospheric sputtering at Titan, Michael and Johnson [6] showed that if the penetration depths are shallow the temperature at the exobase did not increase significantly due to cooling by escape. We see a similar result in our Martian exosphere model for high fluxes and relatively small penetration depths. However, this is not the case for the energetic penetrations ions considered in Fang et al. [2]. Therefore, we have begun a parameter study of atmospheric loss in which we will vary the flux and energy distribution of the incident plasma ions. The goal is to explore the parameter space for production of escape and the formation of the corona in preparation for the expected data from MAVEN on hot atoms and molecules in the Martian exosphere.

Methods: We will use a Direct Simulation Monte Carlo model of a one dimensional oxygen atmosphere. This is a numerical method used to accurately describe rarefied gas flows, where the atmosphere is simulated with representative particles. We will initially assume the incident pick-up ions are primarily O+ which neutralize rapidly in an O corona. The collisions between O atoms in the atmosphere are calculated using O+O cross sections over a broad range of energies [4,8].

We initially use the program TRIM to calculate the heating rate versus column density for a range of ion energies a fluxes varying from 1 to 10 keV oxygen ions at a 55 degree angle of incidence and 1E6 to 1E9) ions/m^2 s. These heating rates were added into the model after the atmosphere reached steady state to examine the resulting coronal expansion and the escape rates.

Summary: For the largest flux and small penetration depths, there is relatively little heating, as the additional energy is enough that the atmosphere cools through escape. As a result, significant escape is found. The less extreme fluxes will be used represent the variation for low to high solar wind activity. The goal of this model is to simulate a wide range of initial conditions for use in interpreting MAVEN data on escape and hot corona structure. To further this goal, we endeavor to add a fluid model to the lower boundary of the DSMC model, to increase the depth of the atmosphere, since higher energy ions can have deep penetration depths. As in our earlier work [4,6], we will use a Monte Carlo particle flux to compare the relative importance of momentum transfer and heating by the incident particle flux

References:

[1] Chaufray, J.Y., et al., "Mars Solar Wind interaction", JGR 112 (2007)., [2] Fang, X., et al., "The Importance of Pickup Oxygen Ion Precipitation to the Mars Upper Atmosphere Under Extreme Solar Wind Conditions", GRL 40, 1-6 (2013)., [3] Jakosky, B., et al., "Mars Atmospheric Loss and Isotopic Fractionation by Solar-Wind-Induced Sputtering", Icarus 111, 271-288 (1994)., [4] Johnson, R.E., et al., "The sputtering of an oxygen thermosphere by energetic O+ ", J. Geophys. Res. 105, 1659-1670 (2000)., [5] Luhmann, J.G., et al., "Evolutionary Impact of Sputtering of the Martian atmosphere", GRL 19, 2151-2154 (1992)., [6] Michael, M. and R.E. Johnson, "Energy deposition of pickup ions and heating of Titan's atmosphere", Planet. & Space Sci. 53, 1510-1514 (2005)., [7] Wang, Y., et al., "Modeling of the O+ pickup ion sputtering efficiency", JGR (2014). [8] Tully, C.& R.E. Johnson, Planet. Sp. Sci. 49, 533 (2001).