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Particle Circulation Model in The Martian Environment: Atmospheric Sputtering

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Abstract

Atmospheric sputtering is a well known process acting on planetary atmospheres in a similar way in which ion-sputtering acts on surfaces of airless bodies. By means of this process, solar/planetary energetic ions that impact on the upper regions of planetary atmospheres may cause evaluable escape. In fact, these energetic particles generate a collision cascade below the exobase, allowing a consistent flux outward from the atmosphere. The yield of the process may be relevant, depending on the number and the kind of the implied collisions.

Mars is the fourth planet in the Solar Sistem, it is a rocky planet with a tenuous atmosphere which interacts with the solar wind plasma. Mars do not possess an intrinsic magnetic field, for this reason, atmospheric sputtering is expected to act more effectively on their atmospheres. To study this process we developed a Montecarlo singleparticle model that simulates the cascade process.

Introduction

There is considerable interest about the atmospheric escape due to the extensive measurements in the planetary and satellite atmospheres made by Cassini in the Titan's atmosphere, MEX- Aspera 3 and MAVEN in the Martian atmosphere, VEX-Aspera 4 in the Venus atmosphere and New Horizons in the Pluto system.
The atmosphere of planets and planetary satellites are typically embedded in the solar wind or in the magnetosphere for the most part of its orbit. Depending on the interaction with the induced or intrinsic magnetic fields, energetic ions can have access to the upper atmosphere and the corona affecting their composition and causing loss to space. Of considerable recent interest is the modeling of escape from atmospheric system. For many solar system body escape is dominated by non-thermal processes (Chaufray et al. 2007, Johnson 2009). All these processes capable to remove species from the upper atmosphere are often called as 'atmospheric sputtering' (Johnson 1994).

Mars model: input parameters

In this work, to study the atmospheric sputtering, we apply a Montecarlo single- particle model. The test-particle trajectory (proton of the solar wind) interacts with the exosphere-atmosphere system producing a significant escape of atmospheric particles. Our simplified model considers Mars' atmosphere and exosphere as composed of CO2, H and O. The neutral profiles population are approximated by an exponential function [Krasnopolsky and Gladstone,1996]. The empirical model of the proton flow is based on ASPERA three Dimensional proton velocity measurements (Kallio [1996]). For a more realistic approach we describe the collision processes between the plasma energetic ions and the exosphere-atmosphere system using different esperimental cross section at 100eV, 1Kev and 10 keV for elastic collision, ionization, e-loss and charge exchange.

Results

The figure 1 shows the bi-dimensional density distribution of the neutral particles in the Martian atmosphere (H, O, and CO2) (log10 scale) within 3 R_M (=Martian radius) as they are produced by SW projectiles.

The figure 2 shows the energy distribution of the particles inside an exospheric volume within 3R_M .The escape velocity from Martian gravitational field is 5Km/s, corresponding to an energy value of 1.2 eV for CO2, 0.44eV for O and 0.027 eV for H (red line in the figures). In the figures we can see that at lower energies the H dominates the distribution, while at higher energies CO2 and O dominate

Conclusion

This preliminary work is intended to develop a model able to predict the behaviour of particle escape through ATMOSPHERIC SPUTTERING. This involves the elastic, charge exchange and electron stripping processes.

We use our model to simulate sputtering escape through some of these processes in two different environments of the Solar System: Mars and Titan. The results show a remarkable contribuiton of atmospheric sputtering to the planetary atmospheric loss, to be considered for atmospheric evolution studies. In the next, the model will include all processes for Titan too and will be applied to Venus, for useful comparisons

Figures

Figure 1 The bi-dimensional density distribution of the neutral particles in the Martian atmosphere (H, O, and CO2) (log10 scale) within 3 R_M (=Martian radius). H (up at left), O (up at right) and CO2 (up),

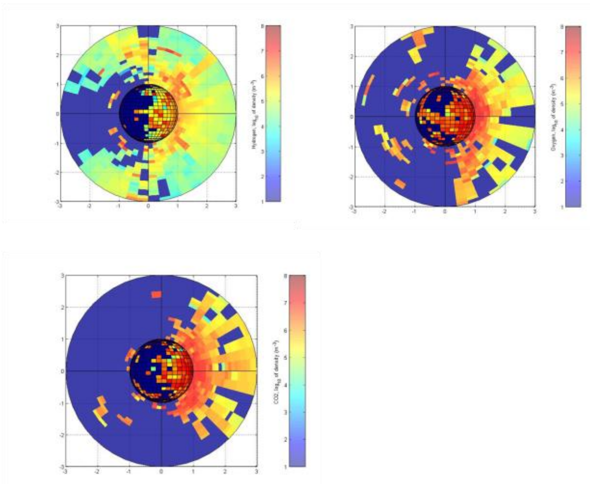
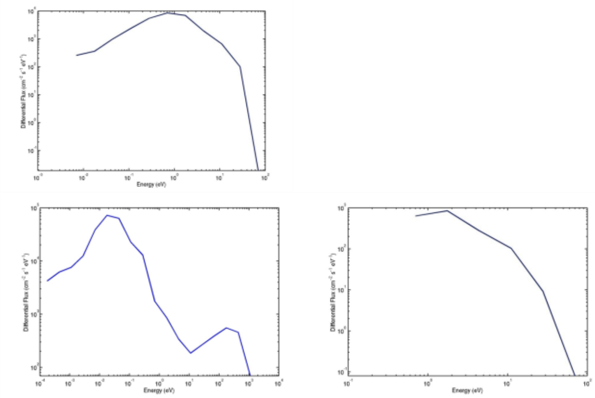


Figure 2 The energy distribution of the particles inside an exospheric volume within 3R_M for CO2 (up), H (down at left) and O (down at right)



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