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Impact induced erosion of hot and dense atmospheres

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Abstract

Previous investigations of impact-induced atmospheric erosion considered mainly crater-forming impacts. Simple estimates show that in dense primary planetary atmospheres, considerable erosion could be induced by aerial bursts resulting from impacts of 1 to 10 km sized projectiles. Numerical simulations of cometary and asteroidal impacts (striking unmodified and crater-forming, impacting as fragmented meteorites, or causing aerial bursts) into dense (200 bar) atmospheres of different temperatures have been performed to obtain the amount of atmospheric erosion. The results have been approximated by simple analytical formulae.

1. Introduction

The evolution of Earth's atmosphere is characterized by source and loss processes. Atmospheres may have evolved by gravitational attraction from the solar nebula, whereas the Earth's atmosphere more likely is a product of volcanic degassing from the mantle and evaporation of volatiles during impact of comets and hydrous asteroids. The growth of atmospheres is counteracted by escape processes primarily due to hypervelocity impacts. The idea of impact-induced planetary atmospheric erosion has been suggested by Cameron (1983). It is based on the assumption that a considerable mass of shock-heated and upwards-accelerated atmospheric gas can reach velocities exceeding u_{esc} = 11.2 km/s (i.e., escape velocity for the Earth) and can be ejected to space.

Quantitative estimates of this mechanism based on different assumptions have been proposed by Vickery and Melosh (1990), Newman et al. (1999), and Shuvalov and Artemieva (2002). Simple approximations treated impacts like surface explosions. The most advanced models (Svetsov, 2007; Shuvalov, 2009) consider the cratering flow induced by impacts of spherical or cylindrical asteroids and comets. De Niem et al. (2012) coupled previously suggested parameterizations of source and loss processes with an estimated impactor flux in a stochastic model to quantify atmospheric evolution; however, they pointed out that a comprehensive description of the impact-induced loss mechanism is lacking. Although Shuvalov (2009) has taken the effects of impact angle and of a wake created during the flight of the projectile through the atmosphere into

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