Impact erosion of planetary atmospheres: parameter dependence of mass loss efficiency

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The atmospheric escape affects the atmospheric mass and composition, and played an important role in the evolution of planetary atmosphere. In addition to thermal escape and non-thermal escape, impacts of asteroids and comets can remove some fraction of the atmosphere. When an impactor hits upon a planetary surface and its huge energy is released at the impact point, the impactor and a part of the target surface are vapolized. The impact-induced vapor is generally very hot and high-pressure. Consequently, the vapor expands rapidly and accelerates the ambient atmosphere. Vickery and Melosh (1991) proposed a simple quantitative physical model and investigated the interaction of the vapor cloud with the atmosphere. In their model, shock is assumed to propagate spherically. They found two criteria for impact erosion of the atmosphere: the lower limit for the impactor velocity and mass. They concluded that if these criteria are satisfied, almost all atmosphere above the plane tangent to the impact point will be removed.

Newmann et al. (1999) simulated the atmosphere motion with a K/T size impact on Venus and Earth and examined a validity of Vickery and Melosh's 'hemispheric blowoff' model. They showed that the vapor cloud would expand rapidly upward and blow off little portion of the overlying atmosphere. Their result shows that the 'hemispheric blowoff' model does not apply to all impacts.   However, they did not investigate the dependence of atmospheric blow off on the impactor size, impact velocity, and atmosheric parameters.

We have developed a two-dimensional hydrodynamic code in cylindrical coordinate system and examined the behavior of a vapor cloud and the planetary atmospheres. We have investigated the dependence of escaping atmospheric and vapor mass on the various impactor velocity, impactor radius and the atmospheric surface pressure and scale hight. It is found that the two kinds of transitions in the mode of atmospheric blow: one is related to the acceleration efficiency depending on the ratio of impactor size and atmospheric scale height, and the other is the pressure dependent change in the shape of the atmospheric zone from where the atmoshere is lost. Owing to the latter transition, the mass lost from the atmospheric is almost independent on the atmospheric pressure for a low atmospheric pressure cases. This result is quite different from any previous studies and has an implication for the role of impact erosion in the evolution of planetary atmospheres.