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Revisited to the impact erosion of early Earth atmosphere during the heavy bombardment period

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Impact-induced expanding vapor clouds resulting from hypervelocity impacts accelerate the srrounding planetary atmosphere. If the velocity of an accelerated atmosphere exceeds the escape velocity of the planet, the atmosphere is lost from the planet. This process is called impact erosion, which has been widely studied since 1980s. Especially, the early dense atmosphere of Mars (~10^5 Pa) was lost due to impact erosion during the heavy bombardment period [Melosh & Vickery, 1989].

In this study, we focused on the impact erosion of early Earth atmosphere during heavy bombardment. Melosh & Vickery (1989) roughly estimated the required impact velocity for the massive blow off of the atmosphere above the tangent plane on the Earth as ~25 km/s. In contrast, the median of impact velocity of asteroids onto the Earth is considered as 13-15 km/s [Chyba, 1991]. Thus, the impact erosion of Earth atmosphere has not been studied well. However, they employed the minimum value of the internal energy of the expanding vapor cloud for a conservative estimate because energy partitioning during hypervelocity impacts at higher than the escape velocity of the Earth was highly uncertain. Now, the Hugoniot curve up to ~1TPa are available obtained using high power lasers. The equation for the internal energy of an expanding vapor cloud is modified using the pressure-entropy Hugoniot curve from the conservative estimate and is incorporated into the sector blow-off model, which is a semi-analytical model for impact erosion due to expanding vapor clouds [Vickery & Melosh, 1990]. We found that the threshold impact velocity for the initiation of atmospheric blow-off estimated by our equation is~13 km/s, which is ~3 km/s smaller than that estimated by the conservative estimate of the internal energy. The significance of the impact erosion of the early Earth atmosphere may be drastically changed from the current understanding because the median of impact velocity between the Earth and asteroids is located between the threshold velocities between both estimates.

In presentation, we are planning to present the systematic results on the change in the total atmospheric pressure as functions of impact velocity, initial atmospheric pressure, the total mass of impactor, the size distribution of impactor and to discuss the atmospheric evolution of the Earth during the heavy bombardment period.

Keywords: Impact-induced vapor clouds, Early Earth atmosphere, Impact erosion, Heavy bombardment period, Solar nebula, Noble gases