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Atmospheric loss in giant impacts depends on pre-impact surface conditions

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Earth likely acquired much of its inventory of volatile elements during the main stage of its formation, and Earth's proto-atmosphere must therefore have survived the giant impacts, collisions between planet-sized bodies, that dominate the latter phases of accretion. We have used a suite of 1D hydrodynamic simulations to quantify the effect that pre-impact surface conditions (such as atmospheric pressure, composition and temperature, and presence of an ocean) have on the efficiency of atmospheric and ocean loss from proto-planets during giant impacts. We find that, in the absence of an ocean, lighter, hotter, and lower-pressure atmospheres are more easily lost. The presence of an ocean can significantly increase the efficiency of atmospheric loss compared to the no-ocean case, with a rapid transition between low and high loss regimes largely controlled by the relative mass of the ocean and atmosphere. However, contrary to previous thinking, the presence of an ocean can also decrease loss if the ocean is not sufficiently massive, typically a few times the atmospheric mass. Atmospheric and ocean loss due to giant impacts is thus highly sensitive to the surface conditions on the colliding bodies. To allow our 1D results to be combined with 3D impact simulations, we have developed scaling laws that relate the surface conditions and ground velocity to the efficiency of loss. We will present preliminary 3D atmospheric-loss calculations and show how 3D and 1D calculations can be combined to more completely explore the dependence of atmospheric and ocean loss on pre-impact surface conditions. Our results demonstrate that the final volatile budgets of planets are critically dependent on the exact timing and sequence of giant impacts experienced by their precursor planetary embryos, making atmospheric properties a highly stochastic outcome of planet formation.