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Atmospheric Evolution due to impacts during the final stage of planet formation

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We investigate how the bombardment of terrestrial planets by populations of planetesimals left over from the planet formation process, asteroids from the main belt and comets affects the evolution of their atmospheres, through both impact induced atmospheric mass loss and volatile delivery. This work builds on previous studies of this topic by combining prescriptions for the atmosphere loss and mass delivery derived from hydrodynamic simulations with results from dynamical modelling of a realistic population of impactors.

The effect on the atmosphere predicted by the hydrodynamical simulations performed by Shuvalov (2009) as a function of the impactor and system properties are incorporated into a stochastic numerical model for the atmospheric evolution. The effects of rare but destructive giant impacts, that can cause non-local atmosphere loss, are also included using the prescription from Schlichting et al. (2015). The effects of aerial bursts and fragmentation of impactors in the atmosphere are included using a prescription based on the work of Shuvalov (2014). These effects are found to be relevant for hot and dense atmospheres analogous to the present day conditions on Venus.

We compare the impact induced atmosphere evolution of Earth, Venus and Mars using impact velocities and probabilities inferred from the results of dynamical models of the population of left over planetesimals in the early solar system from Morbidelli et al. (2018), the population of asteroids from Nesvorny et al. (2017a) and comets from Nesvorny et al. (2017b). We use realistic size distributions for these populations based on the main belt asteroids and trans-Neptunian objects. The effect of the variation in the distribution of the impactor material through their bulk density and volatile fraction is investigated, as is the effect of varying the initial conditions assumed for the atmospheres of Earth, Venus and Mars.

Our results for the Earth are discussed in light of observational constraints regarding the composition of the material delivered as the late veneer. The results for Venus and Mars are

compared to those for the Earth and considered in comparison to observational evidence regarding the past climate of these worlds. A holistic view of the results for all three planets allows constraints on the past atmospheres to be inferred, in the absence of other atmospheric effects.