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The Volatile History of Venus: from Late Veneer to Present-Day.

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We study the volatile history of the atmosphere of Venus and how it evolved depending on volcanism, atmospheric escape and collisions with large asteroids. Specifically, we investigate the long-term evolution of volatiles in the atmosphere of Venus, using self-consistent numerical models of global thermochemical convection coupled with both an atmospheric evolution model and a late veneer N-body model.

We have developed a coupled numerical simulation of the evolution of Venus, striving to identify and model mechanisms that are important to the behaviour of the planet and its surface conditions. Currently the simulations include modelling of mantle dynamics, core evolution (magnetic field generation), volcanism, atmospheric escape (both hydrodynamic and non-thermal), evolution of atmosphere composition, and evolution of surface conditions (greenhouse effect) and the coupling between interior and atmosphere of the planet. We have also modelled the effects of large meteoritic impacts on long term evolution through three aspects: atmosphere erosion, volatile delivery and mantle dynamics perturbation due to energy deposition. We compare the state of the atmosphere of Venus observed at present-day to that obtained from the 4.5 Gyr evolution simulations.

Venus' proximity to the Sun caused extremely efficient early hydrodynamic escape, removing most of this water within the first 100 Myr of its evolution, contrasting with more limited water loss from Earth. Later escape processes are mainly non-thermal and much less efficient but longer lived. They compete with volcanic degassing to keep water content in the atmosphere of Venus at the very low level observed at present-day (20ppmw.). The interaction of non-thermal escape and the volcanic source would be the origin of the high D/H ratio observed in the atmosphere of the planet. This does not, however, precludes a wet Venusian mantle as, at the surface pressures observed today, only 0.1 to 1% of the actual lava water content at most is likely to be released into the atmosphere. CO_2 degassing is not affected in the same way and is likely to be comparatively larger.

By varying the composition and size distribution of the late veneer material, we show that LV impactors should preferentially have a composition similar to that of Enstatite/ordinary chondrites, as opposed to carbon chondrites (volatile rich) to reproduce present-day conditions. CC contribution is thus limited to 0-2% of the total LV mass. Our study thus suggests that the late veneer delivered to Venus was preferentially dry, confirming previous studies based on isotopes for Earth and Mars. Venus and its atmosphere have therefore not received any major volatile delivery after the end of the magma ocean stage and the majority of the volatiles was delivered to the terrestrial planets already during planet formation.