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How Venus surface conditions evolution can be affected by large impacts at long timescales?

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Using numerical simulations, we investigate how the evolution of Venus' atmosphere and mantle is modified by large impacts, during Late Veneer and Late Heavy Bombardment. We propose a coupled model of mantle/atmosphere feedback. We also focus on volatile fluxes in and out of the atmosphere: atmospheric escape and degassing.

The solid part of the planet is simulated using the StagYY code (Armann and Tackley, 2012) and releases volatiles into the atmosphere through degassing. Physical properties are depth-dependent. The assumed rheology is Newtonian diffusion creep plus plastic yielding.

Atmospheric escape modeling involves two different aspects: hydrodynamic escape (0-500 Myr) and non-thermal escape mechanisms (dominant post 4 Ga). Hydrodynamic escape is the massive outflow of volatiles occurring when the solar energy input is strong. Post 4 Ga escape from non-thermal processes is comparatively low.

The evolution of surface temperature is calculated from the greenhouse effect dependent on CO_2 and water concentrations in the atmosphere, using a one-dimensional gray radiative-convective atmosphere model. It allows us to complete the coupling of the model: feedback of the atmosphere on the mantle is obtained by using surface temperature as a boundary condition for the convection.

Large impacts are capable of contributing to (i) atmospheric escape, (ii) volatile replenishment and (iii) energy transfer to the mantle of the solid planet. We test a wide range of impactor parameters (size, velocity, timing) and different assumptions related to impact erosion (Shuvalov, 2010). For energy transfer, 2D distribution of the thermal anomaly created by the impact is used, leading to melting and subjected to transport by the mantle convection.

Small (0-50 km) meteorites have a negligible effect on the global scale: they only affect the impact point and do not have lasting consequences on surface conditions. Medium ones (50-150 km) have strong short term influence through volatile degassing due to the melting of the solid parts of the bodies. Only larger impactors (300+ km) have lasting effects on the planet, though. In all cases, however, atmospheric erosion appears to be mitigated by volatiles brought by the collision.

Long term effects are related to melting and volcanic events triggered by the impact. Those are expected immediately after the impact, but also later on. Depending on when the impact occurs, surface conditions history can change radically. Early impacts can deplete much of the initial volatile content of the mantle, allowing early efficient removal of volatiles due to strong atmospheric escape. This leads to low later degassing if the mantle is not replenished. Later impacts can counteract the effect of atmosphere escape by releasing volatile in a single event. The resulting high surface temperatures affect mantle convection and can prevent mobile lid regime from initiating, with profound consequences for volatile exchanges and mantle evolution. A key factor is thus the timing of the impact and how it interacts with other processes.