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Mantle/atmosphere feedbacks govern coupled Venus evolution: a numerical model.

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We investigate the evolution of the venusian atmosphere and surface conditions and how they are linked with mantle dynamics through a coupled numerical model. Coupling occurs (i) due to mantle degassing, releasing volatiles into the atmosphere, and (ii) through surface temperature that provides a boundary condition for convection processes. We focus on volatile exchange mechanisms.

Loss of volatiles from the atmosphere occurs through atmospheric escape. During early evolution, hydrodynamic escape is dominant. We developed a model that takes into account the linked escape of Hydrogen and Oxygen. It is constrained by isotopic ratios of noble gases fractionated during the escape phase. A significant portion of the early atmosphere can be removed this way. For later evolution, we focus on non-thermal escape mechanisms such as sputtering, ion pick-up and dissociative recombination. Post 4 Ga escape is comparatively low but takes place over a much longer period.

The atmosphere is replenished by volcanic degassing. We use the advanced StagYY code for mantle dynamics to compute the evolution of the interior of Venus and corresponding partial melting and volcanic output. We assume a compressible, anelastic mantle with infinite Prandtl number in 2D, spherical annulus geometry. Rheology is assumed independent of composition and includes Newtonian diffusion creep plus plastic yielding. Volatile fluxes are estimated for different mantle compositions and partitioning ratios.

We use a gray radiative-convective one-dimensional (vertical) model for the atmosphere of Venus, by tracking the evolution of greenhouse gasses in the atmosphere (water and CO_2). Uniform surface temperatures correspond to the conditions on Venus. Cloud evolution is not modeled and cloud coverage is assumed to stay similar to that of present-day Venus. The mantle convection code then uses this temperature as a boundary condition.

We are able to obtain Venus-like behavior for the solid planet, with resurfacing events constituting an efficient way of losing Venus' internal heat and leading to present-day conditions. Resurfacing events occur as patches rather than fully global events, the last of those taking place during the last 100-1000Myr. CO_2 pressure seems unlikely to vary much over the history of the planet, only slightly increasing due to degassing. A late build-up of the atmosphere with several resurfacing events seems unlikely. Water pressure is strongly sensitive to volcanic activity and varies rapidly leading to variations in surface temperatures of up to 200K. We observe a clear negative feedback of the atmosphere on volcanic activity, as higher surface temperatures lead to stagnant or episodic lid convection. Lower surface temperatures favor mobile lid convection, akin to plate tectonics. This regime is however usually short-lived, as increased degassing leads to atmospheric build-up and higher surface temperatures that turn mobile lid into stagnant lid and then episodic lid convection.