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Mantle dynamics and the atmospheres of Mars and Venus: implications for surface conditions and interactions.

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We propose to investigate the interaction between the mantle and the atmosphere of terrestrial planets, in order to study whereas such coupling could be the cause of the divergent evolution of planets in our solar system. Therefore, we build a coupled model taking into account mantle dynamics, volatile exchanges and atmospheric processes. We focus on Mars and Venus and consider the evolution of CO_2 and H_2O in the atmosphere.

The first main mechanism we consider is the volcanic source of volatiles. Therefore we need to model the mantle dynamics by adapting the highly advanced StagYY code (developed by P. Tackley, 2008) for Mars and Venus. When possible, we compare those results to published modeling (Breuer and Spohn, 2006; Grott et al., 2011) and observation. Atmospheric escape is considered as the main volatile loss flux. Early loss is thermal, caused by hydrodynamic escape. After the first few hundred million years, the main atmospheric escape flux is caused by non-thermal mechanisms. We model their evolution by comparing recent numerical study and ASPERA (Analyzer of Space Plasma and EneRgetic Atoms) measurements. We combine these models to calculate the state of the atmosphere of Venus and Mars. This lets us estimate the surface temperature of those planets either from a Mars Global Circulation Model (e.g. Forget at al., 1999), or with a gray radiative-convective atmosphere model, for Venus.

In the case of Mars, we show that the present-day atmosphere of Mars is likely to be constituted by a large part (more than 50%) of volcanic gases emitted since 4 billion years ago, which corresponds to a mean age of 1.9 to 2.3 Gyr. The variations of CO_2 pressure over this period seem relatively low (50 mbar at most). This seems in line with the assumption that the heavy loss of volatiles occurred before 500 Myr. Surface temperature variations are likely to be small (several Kelvin) and would not be responsible for periods of flowing liquid surface water by themselves. Water is abundant on Mars during the whole 4 billion years evolution (between 30% and 150% of the present day water) but is unlikely to reside in the atmosphere or in liquid form.

In the case of Venus, we are able to reproduce resurfacing events (relatively short spikes of high volcanic activity) separated by quieter periods. Atmospheric escape is also much lower than on Mars. During the last 4 Gyr, CO_2 pressure doesn't seem to vary significantly relative to present-day amounts, showing only a slight increase (only several hundreds of mbar). Water pressure, on the other hand, is strongly sensitive to the volcanic activity spikes and degassing. This induces a surface temperature variation of up to several hundreds of Kelvins between the dry atmosphere phase and the period of volcanic activity. The surface temperature variations cause changes in the activity of the mantle, in turn modifying the volcanic activity and degassing, and producing retroactions between atmosphere and mantle.